COHERENT®

USER MANUAL

LEGEND-F

MULTI-KILOHERTZ PULSED TI:SAPPHIRE AMPLIFIER WITH PULSE STRETCHER AND COMPRESSOR

Preface

Copyright

Disclaimer

This manual provides information regarding the operation and maintenance of the Coherent Legend-F.

Every effort has been made to ensure that the information in this manual is accurate. All information in this document is subject to change without notice. Coherent makes no representation or warranty, either express or implied with respect to this document. In no event will Coherent be liable for any direct, indirect, special, incidental or consequential damages resulting from any defects in this documentation.

Coherent personnel will install the laser system. We do not guarantee laser performance unless the laser is installed by Coherent personnel or by an authorized representative of Coherent.

Support Needs

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Specifications

Legend-F Titanium Sapphire Regenerative Amplifier System[1]	
INPUT REQUIREMENTS: from the Mode-Locked Ti:Sapphire laser (Mira)	
Power	>400mW
Wavelength	750 – 950nm (requires correct optics)
Energy Stability	<10% RMS
Pulse Length	<100fs (femtosecond version) <2ps (picosecond version)
Beam Diameter	2-3mm
Polarization	Linear, vertical
Collimating Telescope	1:1
OUTPUT CHARACTERISTICS:	
Pulse Duration	(FWHM)[2] <130fs (femtosecond version) <2ps (picosecond version)
Pulse Broadening	<150% of the input duration
Energy (at 1kHz)	1mJ (after compression, Femto and Pico)
Energy (at 5kHz)	>0.3J (after compression)
Beam Diameter	6-8 mm (nominal)
Energy Stability (±% p/p)	<3%
Polarization	Linear, horizontal

[1] Specifications subject to change without notice. Specifications on purchase order supercede all other published specifications.

[2] For $sech^2$ temporally shaped input pulse only.

Table of Contents

Warning Conventions

The following warnings are used throughout this manual to draw attention to situations or procedures that require extra attention. They warn of hazards to your health, damage to equipment, sensitive procedures, and exceptional circumstances.

Warning Conventions

Danger!	Possible injury or hazard to personal safety
Warning!	Possible damage to equipment
Caution!	Warns against or prevents poor performance or error
Note	Exceptional circumstances or special reference
Danger! Laser Radiation	Laser radiation present
Eyewear Required	Safety eyewear required

1 Laser Safety

Warning!

> This user information is in compliance with section 1040.10 of the CDRH Performance Standards for Laser Products from the Health and Safety Act of 1968. Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.

Danger! Laser Radiation

> Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

1.1 Hazards

Hazards associated with lasers generally fall into the following categories:

- Exposure to laser radiation which may result in damage to the eyes or skin.
- Exposure to chemical hazards such as particulate matter or gaseous substances released as a result of laser material processing or a by-product of the lasing process itself.
- Electrical hazards generated in the laser power supply or associated circuits.
- Secondary hazards such as:
    - X-radiation from faulty power supplies
    - Pressurized lamps, hoses, cylinders, etc.
    - Pressurized liquids and gasses.

1.2 Optical Safety Precautions

The special nature of laser light poses safety hazards not associated with light from conventional sources. The safety precautions listed below are to be read and observed by anyone working with the laser. At all times, ensure that all personnel who operate, maintain or service the laser are protected from accidental or unnecessary exposure to laser radiation exceeding the accessible emission limits listed in 'Performance Standards for Laser Products,' *United States Code of Federal Regulations*, 21CFR1040 10(d).

The following precautions are to observed at all times:

- Wear protective eyewear at all times; selection depends on the wavelength and intensity of the radiation, the conditions of use, and the visual function required. Protective eyewear vendors are

listed in the *Laser Focus World, Lasers and Optronics,* and *Photonics Spectra* buyer's guides. Consult the ANSI, ACGIH, or OSHA standards listed at the end of this section for guidance.

- Avoid wearing jewelry or other objects that may reflect or scatter the beam while using the laser.
- Work in high ambient illumination. This keeps the eye's pupil constricted, thus reducing the possibility of eye damage.
- Never look directly into the laser beam.
- Avoid looking at the beam; even diffuse reflections are hazardous.
- Use an infrared detector to ascertain whether the laser beam is on or off before working on the laser.
- Work with the lowest beam intensity consistent with the application.
- Operate lasers only in well-marked areas with controlled access. Be sure to post appropriate warning signs, clearly visible to all.
- Limit access to the laser system only to qualified personnel who are essential to its operation and who have been trained in the principles of safety. When not in use, lasers should be shut down completely and made off-limits to unauthorized personnel.
- Provide enclosures for beam paths whenever possible.
- Terminate the laser beam with an appropriate energy-absorbing target.
- Shield unnecessary reflections and scattered laser radiation.
- Avoid blocking the output beam or any reflections with any part of your body.
- Set up the laser so that the beam height is either well above or well below eye level

1.3 Electrical Safety Precautions

The following precautions should be observed by anyone when working with potentially hazardous electrical circuitry:

- Disconnect main power lines before working on any electrical equipment when it is not necessary for the equipment to be operating.
- Do not short or ground the power supply output. Protection against possible hazards requires proper connection of the ground terminal on the power cable, and an adequate external ground. Check these connections at the time of installation, and periodically thereafter.
- Never work on electrical equipment unless there is another person nearby who is familiar with the operation and hazards of the equipment, and who is competent to administer first aid.
- When possible, keep one hand away from the equipment to reduce the danger of current flowing through the body if a live circuit is touched accidentally.
- Always use approved, insulated tools when working on equipment.
- Special measurement techniques are required for this system. A technician who has a complete understanding of the system operation and associated electronics must select ground references.

1.4 Interaction From Other Lasers

1.4.1 Mode-Locked Laser

The Legend-F uses a cw mode-locked laser as a seed beam source. The beam from the cw laser is hazardous. Refer to the Operator's manual provided with this laser for additional safety information.

1.4.2 Nd:YLF Laser

The Legend-F uses a pulsed, frequency doubled Nd:YLF laser as a pump source. The beam from the pulsed Nd:YLF laser is hazardous. Refer to the Operator's manual provided with this laser for additional safety information.

1.5 Protective Eye Wear

It is recommended that laser-safe eye wear attenuated to the wavelength of 1047 nanometers and 523.5 nanometers with an optical density (OD) of 7 or higher at each wavelength be worn at all times when the Legend-F laser is operating. Although during normal operation of the laser, the operator should not be exposed directly to diode laser emission, hazardous diode radiation is present in the laser diode pump head. Consequently it is recommended that the eye wear selected for use with the Legend-F should also provide optical attenuation of OD 7 or higher at the diode emission wavelength of (797±2) nm.

1.6 Controls

Any modification or use of the Legend-F laser which changes, disables, or overrides the function of the engineering controls and safety features invalidates the Class IV certification of the laser described in this manual. The safety features incorporated in the Legend-F are described below in the section entitled 'CDRH Compliance'.

1.7 CDRH Compliance

The output powers and energies of the Legend-F laser are hazardous. The following safety features incorporated in the Legend-F conform to Federal performance standard as required by 21 CFR 1040.10(h)(1)(iv):

Key Switch
A separate key switch is provided to enable power to the laser. The key cannot be removed from the switch except in the OFF position. This assures that use of the laser by unauthorized or unqualified personnel can be prevented.

Protective Housings
An internal cover is installed to cover the laser beam path until it exits the optical cavity

at the front (output) port. The diode-pumped head is also contained within its own internal housing to shield the user from stray diode light and to protect the laser diodes from exposure to dust and electrostatic discharge. The Legend-F laser should not be operated with the internal covers removed, or displaced, except when necessary during required service functions such as optical realignment. In particular, removal of the diode pump head cover will invalidate your warranty.

Remote Interlock Connector

The remote interlock connector (marked 'INTERLOCK') at the rear of the power supply cabinet enables the user to connect an external interlock (such as a switch on the door to a laser room, for example). This interlock circuit should be used to terminate laser action automatically if anyone enters the laser operating area. This function causes the diodes to switch off when the interlock contacts are opened. Lasing can only be resumed by closing the external interlock circuit contacts and then cycling the key switch to clear the interlock function. The laser should NOT be operated unless the remote interlock function is in use.

Emission Indicators

Three emission warning indicators are used on the Legend-F laser. After the user presses and holds the laser 'ON' button on the remote control box, an LED indicator on the remote control box flashes to warn personnel that the laser is about to emit laser light. An indicator light on the front of the laser bench also lights any time current is supplied to the laser diodes. This warns the user that the user may be exposed to hazardous laser diode emission inside the laser, even though the laser cavity may not be emitting green or infrared laser light. A third indicator light on the front of the laser bench lights when the laser is activated and the intracavity shutter is opened. This warns that the laser is about to emit laser radiation. All emission indictors remain on as along as the laser is capable of lasing. The indicators light several seconds prior to actual emission to give nearby personnel time to avoid exposure to laser radiation.

Beam Safety Shutter

A solenoid-actuated safety shutter is mounted in the optical cavity to interrupt laser action when necessary. The shutter is actuated when the laser 'ON' button is activated on the remote control box.

Beam Attenuator (Output Port)

A manually operated shutter mounted on the laser output port is provided for blocking of the beam if required.

Location Of Controls

Controls for operation of the Legend-F laser are located on the remote control box so that operators need not be exposed to laser radiation during operation of the laser.

Warning Labels

Certification and warning labels are affixed to the Legend-F laser to verify compliance with 21 CFR 1040, to provide information on the wavelength and power emitted, and to warn the user against accidental exposure to laser radiation. The location and type of warning logotype labels used on the Legend-F laser power supply and bench are shown in Figure 2.1

Operating Instructions

This manual contains instructions for operating and maintaining the Legend-F laser safely.

1.8 Sources of Additional Information

The following are some sources for additional information on laser safety standards and safety equipment and training.

1.8.1 Laser Safety Standards

SAFE USE OF LASERS (Z136.1)
AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)
1430 BROADWAY
NEW YORK, NY 10018
TEL: (212) 354-3300

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)
U.S. DEPARTMENT OF LABOR
200 CONSTITUTION AVENUE N.W.
WASHINGTON, DC 20210

A GUIDE FOR CONTROL OF LASER HAZARDS
AMERICAN CONFERENCE OF GOVERNMENTAL AND INDUSTRIAL HYGIENISTS (ACGIH)
6500 GLENWAY AVENUE, BLDG. D-7
CINCINNATI, OH 45211
TEL: (513) 661-7881

LASER SAFETY GUIDE
LASER INSTITUTE OF AMERICA
12424 RESEARCH PARKWAY, SUITE 130
ORLANDO, FL 32826
TEL: (407) 380-1553

1.8.2 Equipment and Training

LASER FOCUS BUYER'S GUIDE
LASER FOCUS WORLD
ONE TECHNOLOGY PARK DRIVE
P.O. BOX 989
WESTFORD, MA 01886-9938
TEL: (508) 692-0700

PHOTONICS SPECTRA BUYER'S GUIDE
PHOTONICS SPECTRA
BERKSHIRE COMMON
PITTSFIELD, MA 01202-4949
TEL: (413) 499-0514

LASERS AND OPTRONICS BUYER'S GUIDE
LASERS AND OPTRONICS
301 GIBRALTAR DR.
P.O. BOX 650
MORRIS PLAINS, NJ 07950-0650
TEL: (210) 292-5100

2 System Start-Up and Shut-Down

2.1 Unpacking and Installation

Your Legend-F was packed with great care, and its container was inspected prior to shipment. Upon receiving your system, inspect the outside of the containers immediately. If there is any major damage (holes in the containers, water damage, crushing, etc.) insist that a representative of the carrier be present when you unpack the contents.

Keep the shipping crates. If you file a damage claim, you may need them to demonstrate that the damage occurred as a result of shipping. If you need to return the system for service at a later date, the specially designed container will assure adequate protection.

The Legend-F can now be moved to the location in which it will be installed.

Warning!

Do not attempt to install the laser yourself, or remove the lid covering the optical cavity of the laser head. Either action, if unauthorized, will void your warranty, and you will be charged for the repair of any damage incurred if you attempt installation yourself.

2.2 Start-Up Procedure

1. Turn on the external city water supply.
2. Turn on the system chiller.
3. Turn on the Millennia laser and initiate the start-up procedure as described in the Seed Oscillator manual.

   Ensure that the unit is operating under the standard performance specification as stated by Coherent.
4. Remove the Legend-F external, black Plexiglass covers.
5. Turn on the pump laser as described in the "Pump laser manual"
6. Override the mechanical shutter (closes in absence of the top covers) that allows the 527nm pump beam to propagate to the Ti:Sapphire rod in the Regen cavity.

7. Ensure "enable on" switch that provides the trigger signal to the Pockels cell drivers, located on the front panel of the SDG, is disabled (downward position).
8. Power up the Synchronization Delay Generator (SDG) by toggling the switch located behind the SDG unit to the "1" position.

2.3 Daily Performance Optimization

Following parameters are check points that should be followed on a day to day basis in order to ensure that the entire system is well optimized as a whole.

1. Following sufficient warm-up time, ensure Seed Oscillator is well Mode-locked and performing within system specification. Typical oscillator bandwidth should be 35nm centered at 800nm.
2. Ensure good performance from the Pump laser pump source i.e.: power and stability.
3. Ensure Regen amplifier performance.
4. Good seed alignment of the seed source into the Regen amplifier.

2.4 Shut-Down Procedure

1. Disable the trigger signal to the Pockels cell drivers by switching the toggle switch, located on the front panel of the SDG, to the **downward** position.
2. Power down the Synchronization Delay Generator (SDG) by toggling the switch located behind the SDG unit to the **"0"** position.
3. Turn "off" the Pump laser pump laser as described in the Pump laser manual.
4. Power down the Seed Oscillator lasers as described in the Seed Oscillator manual.
5. Turn "off" the system chiller.
6. Turn "off" the external city water supply.
7. If not in place already, replace the Legend-F black, external Plexiglas covers back onto the unit.

3 Stretcher Alignment Procedure

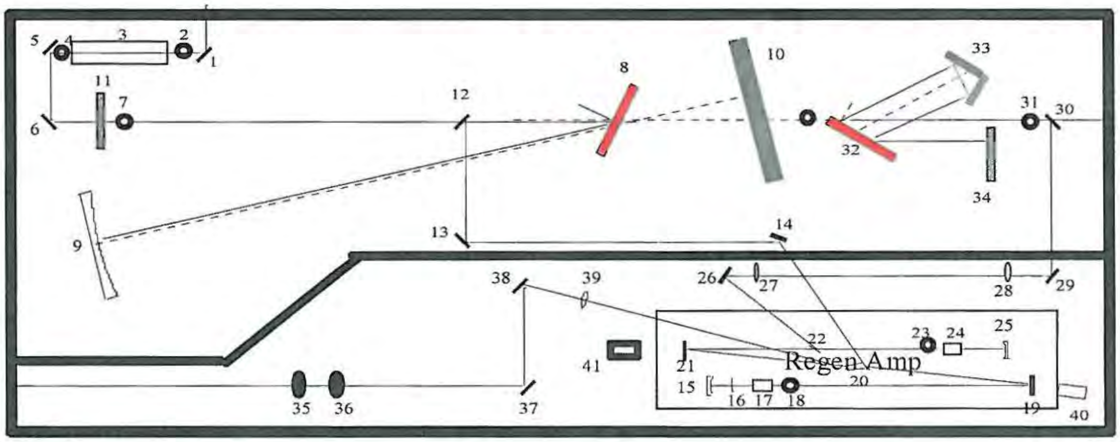

Fig. 3.1 Legend-F layout

The layout of the Legend-F Sub-30 fs Ti:Sapphire Amplifier is shown in Fig. 3.1. The system consists of three main parts. The first part is the stretcher including the components from #8 to #11 (see also Fig. 3.2). The second part is the regen amplifier, which is the components from #15 to #25, and the last part is the compressor, which consists of the components from #32 to #34. The alignment procedure of these three main parts will be discussed in details in the following chapters.

3.1 Stretcher Alignment Check

Fig. 3.2 The photo of the stretcher.

Warning!

> When handling the Stertcher/Compressor grating block, always use finger cots in order to minimize the chance of accidently touching any part of the grating surfaces.

5. Disable the High Speed Drivers from firing by toggling the "Output Enable" switch located on the front panel of the Synchronization Delay Generator, to the downward position.
6. Toggle the mechanical shutter switch located on the front panel of the Pump laser remote box to the "off" position disabling any laser light from emitting from within the laser cavity.
7. Set the wavelength of the Seed Oscillator at or near the peak (i.e. center wavelength @ ~ 800nm). Mode locking <u>is not</u> necessary at this time.
8. Depress the mode-lock enable button
9. Momentarily close and open mechanical shutter to the Millennia laser if step a fails to cause Seed Oscillator to loose mode-lock.
10. Collapse fully reference iris #2 and #4 located on both sides of the Faraday Isolator (comp. #3).
11. Using an Infared viewer, ensure that the Seed Oscillator output beam is propagating simutaneously through the center of the two collapsed irises. If it is not, one will need to steer the beam using the external routing mirror mount located at the output of the Seed Oscillator and mirror #1.
12. Make vertical and horizontal adjustments to the external mirror mount so that the beam is clearly propagating directly through the center of iris #2. Conversly, make the necassry adjustments to both the X and Y axis of mirror #1 so that the beam is propagagting through the center of iris #4.
13. Continue going back and forth between the two mirror mounts mentioned above, while making the necassary X and Y adjustments until the beam is through the center of the two aperatures simutaneously.
14. Open **<u>completely</u>** iris 2 and 4.
15. Wearing finger cots and taking great care not to touch the grating surface. Use a 3/16 ball driver to carefully unscrew the two ¼ -20 screws that secure the top sub-plate to the rotation stage of the stretcher block (#8) as shown in the following picture.
16. Place the subplate housing the grating in a safe and secure location.
17. Place the removable reference iris into the post holder situated directly in front of the stretcher vertical retro mount #7. Collase the iris fully and make sure that the iris apearture is square to the in-coming Seed Oscillator beam.
18. The beam height following the two 45 degree dielectric mirrors should be at 3.5". Using an infared viewer, check to see that the Seed Oscillator beam is propagating directly through the center of the removable iris. If it is not, make the necassry X and/or Y adjustments to the 45 degree mirror/mount (#5) so that the beam is through the center of the aperature.
19. Move the removable iris into the second iris post holder at location #31, situated directly in front of the square 1"x 1" turning mirror #30. The Seed Oscillator beam should again be propagating

directly through the center of the removable iris. If it is not, make the necessary adjustments to the 45 degree mirror/mount #6 until it is. Iterate between steps 9-11 until the beam is propagating directly through the iris center when the iris is situated at both positions.

20. Once the above conditon is acompplished, place the removable iris back into the iris post holder at location 7. Ensure that the iris opening is again square to the in-coming beam and fully collapsed.
21. Momentarily close the mechanical shutter located on the seed input panel.
22. Using finger cots, place the stretcher garting block back onto the rotation stage of the assembly. Re-secure the subplate by screwing the two ¼-20 screws back to the rotation stage.

3.2 Checking Alignment/Setup of the Stretcher Block

Warning!

When handling the Stertcher/Compressor grating block, always use finger cots in order to minimize the chance of accidently touching any part of the grating surfaces.

1. Open the mechanical shutter, allowing the Tsuanmi beam to propagate into the Legend-F .
2. Unlock the rotation stage set screw located at the base of the grating assembly as shown in Fig. 3.3.
3. Using an infared viewer or an IR card, rotate the upper portion of the grating stage so that the surface of the stretcher grating appears to be retro reflecting the Seed Oscillator beam back towards the iris at location 7. See grating orientation shown below in Fig.3.4

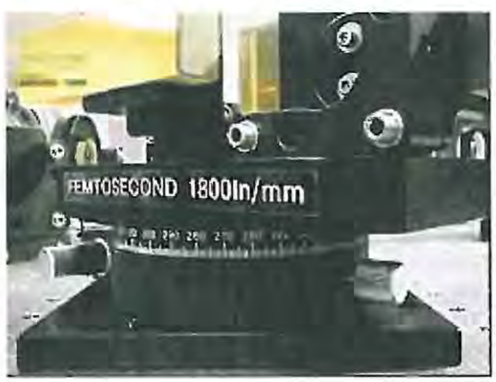

Fig. 3.3 Rotation set screw indicated by arrow as shown above

Fig. 3.4 Stretcher grating alignment for the zero order surface reflection.

4. At this time it is not important that the retro reflection is exactly through the iris .What is important is that the retro reflection coming off the grating is propagating back to the iris at the same height as it is going into the stretcher assembly.

   Once the zero order surface reflection is at or near the iris, relock the rotation set screw. Make the necessary adjustment to the "fine" rotation adjustment screw located on the rotation stage as to place the zero order reflection where it is visible near the iris.

   If the zero order reflection appears to be off in height (3.5"), using a 1/8 balldriver make an adjustemnt to the vertical axis of the mirror mount holding the stretcher grating.

5. Unlock the rotation set screw.

6. Rotate the grating assembly clockwise while looking for the first order reflection from the stretcher grating to be propagating back to the iris at location 7.

7. Lock the rotation set screw once the reflection is near the iris. If the retro reflection appears not to be at the same height as the iris center, loosen the two 3/32 screws that contain the retainer rings (see Fig. 3.5) behind the mirror mount just enough to allow coarse rotation of the entire grating mount. Using a 1/16 ball driver, loosen slightly the set screw holding the grating holder within the mirror mount aperature. With one hand, rotate the grating/holder so that the first order retro reflection appears to be propagating back to the iris center beam height.

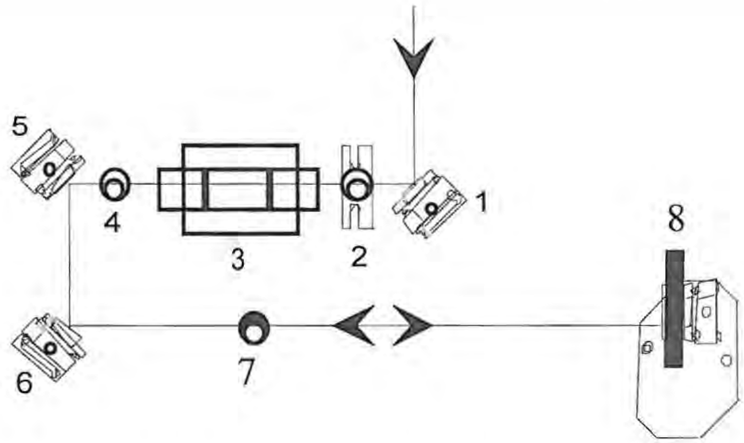

Fig. 3.5 Two 3/32 screws that lock the retain rings behind the mirror mount are used to adjust the grating rotation in the vertical plane.

8. Unlock the rotation set screw and again rotate the entire grating assembly so that the zero order retro reflection is again visible near the aperature of the iris. Lock the set screw. Again check to see that the grating reflection is still at the same height as the iris. If it is not, then again make a vertical adjustment to the mirror mount.
9. Unlock the rotation set screw and rotate the grating block so that the first order reflection is again near the iris. Check to see that it is still at the same height as the iris center. If it not, re-do step 5.
10. Iterate between step 3 and 7 until both the zero and first order reflections are propagating off the grating surface at the same height as the iris center.
11. Once the zero and first order reflections appear to be at the same height, tighten both the 1/6 set screw and the two 3/32 balldriver screws. Check to see that after both have been tightened, that the height of the two order reflections has not changed relative to the iris center. If one or both has, reloosen the screws and attempt to compensate by off-setting the height that the beams propagate prior to tightening the the screw.

3.3 Checking the Setup of the Large Reflective Gold Mirror

1. Using an infared viewer, rotate the grating assembly so that the first order reflection of the stretcher grating appears to be stricking the center (horizontally) of the large gold reflective mirror.
2. Using the viewer, observe the stretcher grating surface. With the removable iris still located directly in front of the vertical retro reflector, one should see two spots located near the center of the grating surface. See Fig. 3.6.

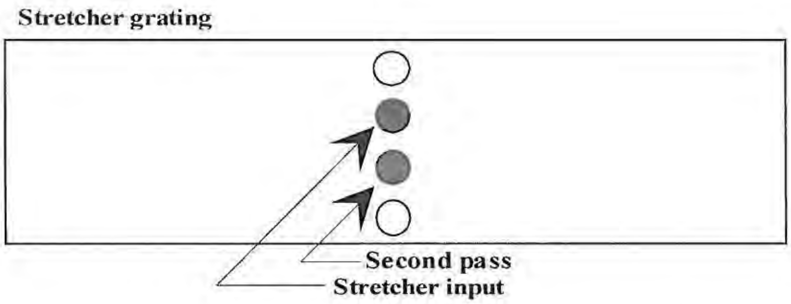

Fig. 3.6 The top spot is the seeding beam from Seed Oscillator. The second spot is the beam reflected from the retro-reflection mirror behind the stretcher grating.

3. If the iris were not in place and the setup of the stretcher was ok, one would see 4 spots lined vertically over one another. Each spot representing one pass within the stretcher setup as shown in Fig. 3.7.

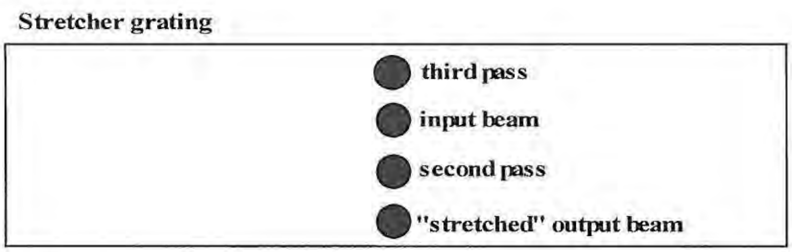

Fig. 3.7 Four spots on the stretcher grating.

4. Tweak the vertical micrometer adjustment knob (Fig. 3.8) located behind the large gold mirror mount clockwise until the surface reflection from the large gold mirror appears to be in the same condition as shown above.

Fig. .3.8 This picture shows the vertical micrometer knob for the 6" diameter gold mirror.

In making the above adjustment, the purpose of the procedure is to:

a) check the setup of the large gold mirror horizontally

b) check the mechanical integrety of the vertical axis of the large gold mirror mount ensureing that the beam does not appear to be moving horizontally as the vertical adjustment is being made. It is very important that it **only** move vertically. If it is not moving vertically, the stretcher setup will not be optimized leading to potential problems recompressing.

If the beam is moving horizontally while making a vertical adjustment following step 4, with the mount in place,

- check the tightness of all the 3/16 screws on the mount.
- Ensure the mirror is flat within the holder and secure via the nylon tip set screw located at the top of the mount

Ensure the micrometer adjustment screw tip is lubricated using, for example, Krytox grease

5. If after doing step 4, the beam from the large gold mirror appears to be off horizontally (not lining up as shown in Fig. 3.6) on the grating surface by more than ½ a cm, one will need to make a coarse adjustment by loosening the baseplate to the large mirror mount and physically rotating the entire mount the amount nesassary in order to setup the mirror so that the two spots line up vertically as shown in Fig. 3.6. If the two spots are off set by less than ½ cm then simply adjust the 'fine" rotation micrometer knob so that they line up vertically.

6. Readjust the vertical micrometer knob to the large mirrror mount counter clockwise forcing the beam from the large gold mirror to go up and over the grating stage assembly ultimately stricking the lower most part of the 1" × 7" dielectric retro reflector (#10). Position the beam on the 1" × 7" mirror (Fig. 3.9) so that it is @ 3-4mm above the bottom edge of the mirror.

If the mechanics of the large mirror mount are sound, the beam from the large gold mirror should be stricking the above mirror at or near the bottom of the mirror and centered horizontally. If it is

not, loosen the nylon tip set holding the 1" × 7" mirror and position it within the mount so that the beam is near center (horizontally).

Fig. 3.9 The arrow shows the 1" x 7" retro-rflection mirror behind the stretcher grating.

7. With the viewer, following the above step, observe the stretcher grating once again. Again one should see the two spots lined up vertically. If the lower spot appears to be off horizontally, adjust the horizontal axis of the 1" × 7" retro reflector so that the lower spot is located directly below the input spot horizontally. Tweek if necessary the vertical axis of the 1" × 7" retro reflector so that the lower spot is @ 3-4mm below the input spot.
8. Remove the "removable" iris from within the iris holder.
9. Observe the stretcher grating surface once again. One should now see four spots lined vertically over one another as shown following step 3 above.
10. If the upper and lower spots appear to be off horizontally with respect to the two inner spots (see Fig. 3.10), adjust the horizontal axis of the upper mirror mount of the vertical retro assembly so that the upper and lower spots line up.

    A second check point to observe is at the 1"×7" retro mirror location. If the vertical retro reflector is aligned correctly both in the X and Y-axis, one should only see one spot. If two spots are visible, tweak the X and/or Y-axis of the vertical retro reflector so that the second spot visible is super imposed upon the main beam. When this is the case, all four spots should line up vertically.

Stretcher grating

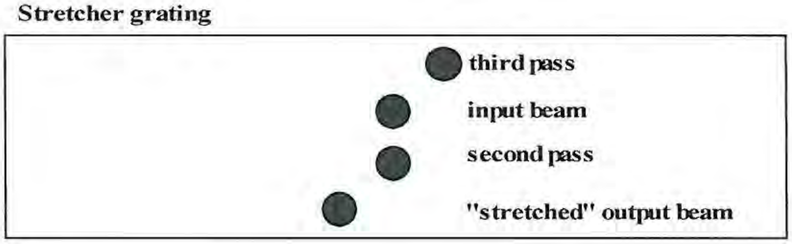

Fig. 3.10 The misalignment of the 1" x 7" reflection mirror.

11. Mode-lock the Seed Oscillator and ensure optimum performance. When this is the case, one should be able to observe the following pattern (Fig. 3.11) on the grating surface. If the two "strips" appear shifted horizontally, make a slight rotation to the grating block so they appear as shown below.

Stretcher grating

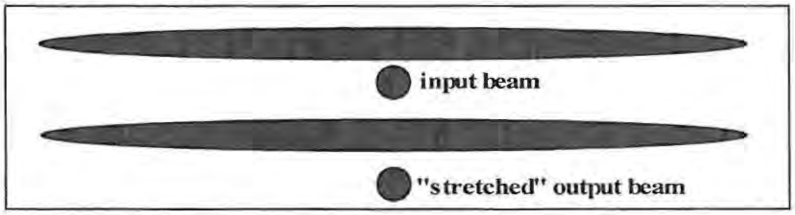

Fig. 3.11 The optimum performance of the spectrum pattern on the stretcher grating.

3.4 Spatial Chirp Free Alignment

The stretcher setup (distance of retro reflector to large gold mirror) is preset at Coherent prior to shipment. However, if at installation, the Seed Oscillator is setup greater than 3.5' away, the divergence of the beam entering the Legend-F is probably going to be different from the divergence of the Seed Oscillator used at the factory. Some reoptiminzation of the stretcher setup may be necessary.

Operation of the Pump laser will not be necessary at this time.

3.4.1 Preparation and Setup of the Spectrometer

1. Ensure that the Seed Oscillator is performing to system specification and well Mode-locked.
2. Ensure that the beam from the Seed Oscillator is well collimated. Reroute the beam from the Seed Oscillators present location and allow the beam to propagate 6 meters or more to the far field. If the layout of the Seed Oscillator is 3 feet or more away from the time the beam exits from the Seed Oscillator to the time the beam enter the Legend-F , a 1:1 telescope is recommended (for instances two 100mm broadband lenses). Install the telescope, ensuring that the beam is well collimated thereafter.
3. Setup a spectrometer at the output of the Legend-F or somewhere appropriate on the system bench.
4. Observe the spectrum from the output of the Seed Oscillator. Note the bandwidth and wavelength in its current operation. Typical output spectrum from the Seed Oscillator should be as smooth as possible with no apparent modulation as shown in Fig. 3.12.

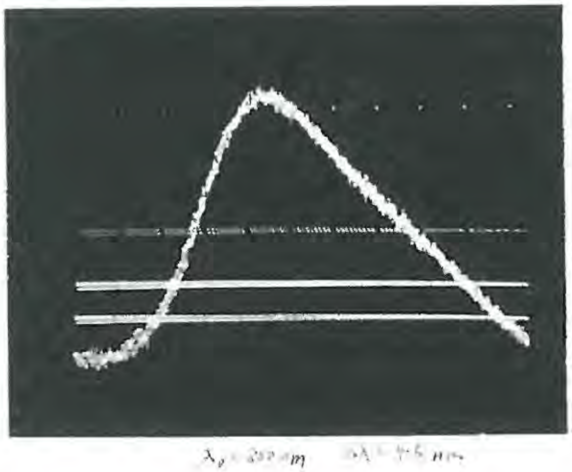

Fig. 3.12 Typical Seed Oscillator Spectrum peak @ 800nm. Bandwidth ≈45nm (calibration = 10 nm/div)

5. Remove the output panel of the Legend-F by backing out the corresponding set-screws located on the two support brackets.
6. Place a mirror between mirror #12 and #13 and setup an external turning mirror to direct the stretched output beam into the spectrometer as shown in Fig. 3.13.

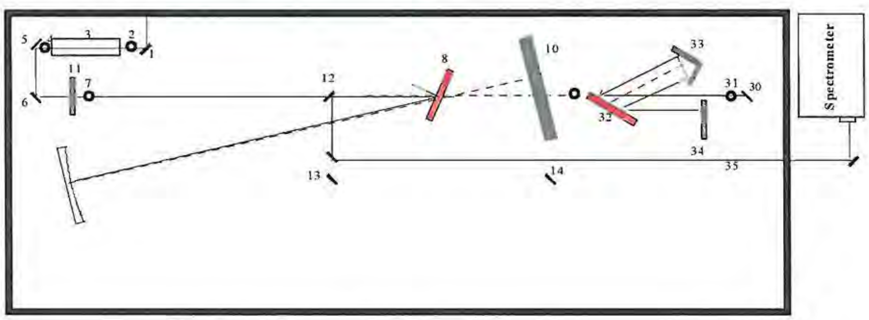

Fig. 3.13 Spatial-chirp-free alignment setup.

7. Setup the spectrometer to be able to monitor the spectrum from the stretcher using an oscilloscope.
8. Connect a BNC cable from the "Trigger out" of the spectrometer to the time base of the oscilloscope. Set the time base to 1ms/div.
9. Connect a second BNC cable to one end of the Spectrometer "signal " out. Connect the other end to the oscilloscope amplifier base. Set the amplitude of the monitored spectrum such that the signal is not saturated.
10. Tweak the horizontal axis of the <u>external</u> mirror used to route the beam into the spectrometer. Observe the spectrum on the oscilloscope. If the Stretcher is not setup correctly, there will be a spatial chirp (spatially varying spectrum). This spatial chirp is caused by the fact that the 1"x 7" mirror (#10) is not exactly at the actual focus of the large curved gold mirror (given the input divergence). Upon tweaking the external mirror, the signal present on the oscilloscope should not

"sweep" left or right on the screen. If this is the case, one will need to optimize the distance of the 1"x 7" mirror relative to the gold mirror so that the spectrum immediately collapses when adjusting the external mirror.

3.4.2 Spatial-Chirp-Free Setup Procedure

1. Ensure Seed Oscillator is well mode locked
2. Ensure stretcher is prematurely setup following the " Stretcher alignment check" procedure.
3. Reference, if possible, the base plate of the 1" × 7" mirror mount to the breadboard in its current position. As a second reference, with the Pump laser shutter closed and the Seed Oscillator beam blocked from entering the Legend-F , using a tape measure, measure the exact distance between the surface of the large gold mirror and the surface of component #10, while in its current position.
4. Loosen the 3/32 screw securing the 1" × 7" mirror mount (#10) to the breadboard. Loosen it such that the base plate remains flat to the bench but not so snug such that the mount will not be able to slide back and forth.
5. If after loosening the base plate the monitored spectrum signal on the oscilloscope has changed, use an infrared viewer to observe the stretcher grating. The alignment on the stretcher grating may appear to be changed vertically. If this is so, tweak the micrometer (vertical axis) located at the back of the large gold mirror so that the grating alignment appears normal. This should recover the monitored signal back on the oscilloscope.
6. Slide in one direction, the mount housing the 1" × 7'' mirror, by millimeter increments.
7. Using an infrared viewer, observe the grating surface. Ensure that the strips appear to be centered to the grating aperture after each increment change. If they are not, reposition them horizontally by adjusting the entire 1" × 7'' mirror mount.
8. After changing distance by a millimeter and optimizing for any horizontal shift, tweak the horizontal axis of the external mirror to check the spatial chirp on the oscilloscope.
9. The further or closer the 1" × 7'' mirror is to the optimum distance of the actual focal length, the broader the monitored spectrum will appear to sweep across the scope screen when adjusting the horizontal axis of the external mirror. Fig. 3.14 and 3.15 show the spectrum before and after the stretcher.
10. After correcting for the 'spatial chirp" in the stretcher, lock the 1" × 7'' mirror/mount to the breadboard, ensuring that the strips on the grating are lined up correctly.
11. Tweak the micrometer adjustment of the gold mirror so that all the four passes within the stretcher are fitted within the grating aperture without clipping..
12. Remove the mirror placed between the mirrors #12 and #13.
13. Follow the procedure "optimizing the seed beam to the Regen cavity".

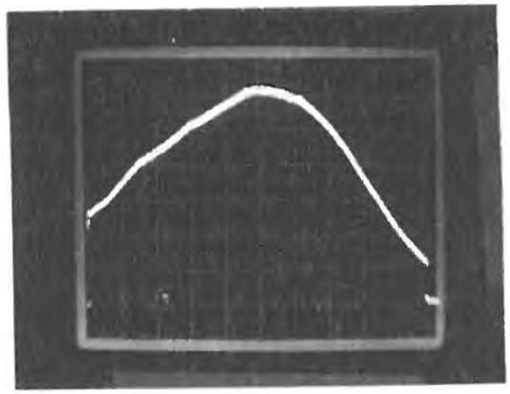

Fig. 3.14 Typical spectrum measured from Seed Oscillator. (Center wavelength @ 795 nm, Bandwidth = 35 nm, calibration is 4.4 nm/ms)

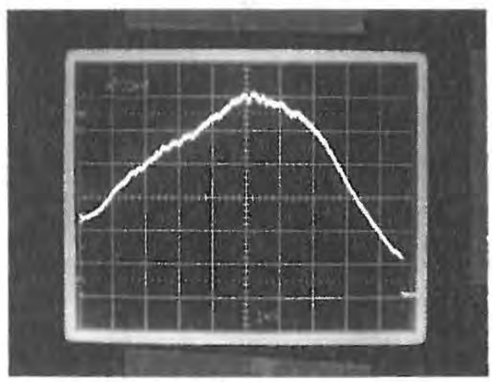

Fig. 3.15 Typical spectrum measured after the stretcher. (Center @795 nm. Bandwidth = 31nm)

4 Regen Alignment Procedure

4.1 Regen. Alignment

Handle all optics while wearing finger cots.

The following procedure explains in detail how to do an alignment of the Legend-F Regen cavity only when the intracavity alignment has been grossly misaligned.

Since most optics will need to be removed from their holder(s) at this time, visually inspect all optics carefully to ensure that no other optics may have also damaged when damage to the rod occurred.

If upon inspection, some of the optics are found to be dirty, clean using methanol/acetone at this time.

Materials needed:

lens tissue

Hemostats

Methanol/acetone

two sheets of polarizer sheets

two Reference blocks with crosshair target set at 2.5"

45 degree turning mirror/mount

1) Using a 3/16-ball driver, remove mirror #15 of the regen cavity from within its mount. Place it near the mount on top of a piece of lens tissue with the coated side facing upward as not to scratch the coating.

2) For reference purposes, if not already, inscribe a mark on the white Teflon holder relative to the position of the setscrew at the top of the mount. Remove the ¼ waveplate (#16) from within its holder.

3) Ensure that reference iris #17 is completely open.

4) Remove Pockels cell #18 from within its holder by:

Note: prior to completely removing the Pockels cell from within their mount, note the current orientation of the cell so that it is replaced back in its original setup. The Pockels cell windows have a slight wedge so the

orientation (placement) of the Pockels cell will deviate the beam passing through the cell horizontally by 5mm in either direction.

A. Indexing the base of the Pockels cell mount in their current position as to maintain a reference. Unscrew the two ¼-20 screws securing the mount to the breadboard and remove the entire assembly and place away from the cavity as allowed by the cable lengths.

B. Removing only the Pockels cell from within mount. Follow "a-f"

a) Ensure SDG is turned off. High voltage present at Pockels cell leads if unit not turned off.

b) Un-plug the 120vac plug leading from the SDG to the input panel of the Legend-F .

c) Using a 3/32 balldriver, remove the four screws located on top of the Pockels cell High voltage cover.

d) Using a 8/32-socket head driver, remove the two hex nut screws securing the High Speed Driver High Voltage leads to the Sol Gel Pockels cell.

e) Using the 3/32 ball driver loosen the support bracket(s) that secures the cell within the mount.

f) Remove the cell from within the mount and place in secure location away from the Regen cavity.

5) Remove the zero degree turning mirror (#19) that folds the Regen cavity from within its mount. Also place at or near the mount.

6) Remove component #41 that serves as the beam dump used to dump the residual 527nm beam after pumping the Ti:Sapphire rod

7) Remove the vertical plate of component #13 by unscrewing the two 8/32 screws located at the base of the mount. Doing so will minimize replacement of the vertical plate once the polarization rotator is re-assembled upon completing the alignment of the Regen cavity.

Upon removal of the vertical plate, the output of the stretcher beam, as it takes a 90 degree turn off of component #12, should now be propagating towards the side panel closest to the Regen cavity.

8) Tweak the vertical axis of mirror #12 so that the beam coming out off the 1"x 1" square mirror is propagating along the tabletop at 2.5".

9) Taking a separate 45 degree mirror (dielectric broadband, gold or silver coated)/mount. Position it such that the beam from the 1"x1" square mirror is turned 90 degrees, propagating along side the panel, towards the output end of the Legend-F as shown in Fig. .4.1.

Note: conveniently, one can use mirror/mount #14 to serve as the component for use as the second turning mirror for optically aligning of the Regen cavity using the stretched output beam as the alignment source. If one chooses this component as the second alignment mirror/mount, flip the mount 90 degrees upon its base plate and at the same time rotate the variable base plate so that the round variable locking ring is located directly in front of where the actual mirror is located within the mount. Reposition component #14 behind the Regen cavity as shown on the following diagram.

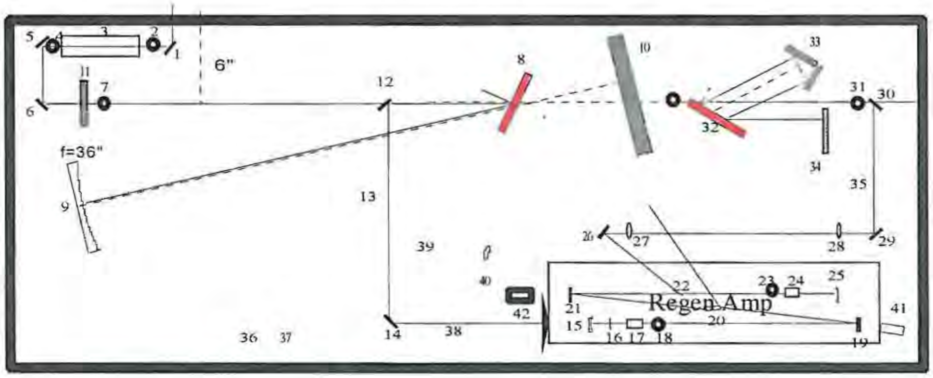

Fig. 4.1 Use mirror #14 as a turning mirror for the pre-alignment of the regen cavity.

10) Set a block with a cross pattern at exactly 2.5" above the Legend-F (serves as a reference target) breadboard directly on top of the last hole of row #2. Place the block with its bottom line of the cross pattern centered directly to the hole center.

11) Without permanently locking component #14 to the breadboard, in a coarse manner, maneuver mirror mount #14 in its new location such that the intercepted stretched output beam appears to be propagating parallel to the Regen side panel along hole pattern #2 of the Legend-F bench.

    Use the reference block mentioned above as the far field reference target.

12) Using a second reference block, place the cross hair target directly on top of the hole (hole pattern #2) closest to component #14. Observe where the beam is relative to the cross pattern. Move the mount according to the direction the beam needs to go relative to the cross pattern.

13) Remove the block.

14) Once the position of the mount is such that the beam is close to the referenced holes along row #2, using a 3/32 screw, lock component #14 to the bench so that it is secure.

15) Once the mount is secured to the tabletop, observe where the beam is relative to the reference cross hair on the mount located towards the output panel of the Legend-F . The beam should be sticking the cross hair target center. If it is not, make the necessary adjustments to the X and Y-axis of mirror/mount #14 so that it is.

16) Place the second reference block (or relocate the block nearest the output panel) directly on top the hole referred to in step 10. Observe where the beam is relative to the center of the cross hair. If it is not centered to the cross hair target, make the necessary adjustments to the X and Y-axis of the 1"x1" mirror/mount #12 so that it is

17) Continue steps 10-12 until the beam is perfectly centered to the crosshair patterns at both locations along row #2 of the breadboard.

18) Position the mirror mount #15 (if necessary) so that the "exposed" mirror aperture of the mount is centered to the in-coming "stretched" beam.

19) Place the ¼ waveplate back into its holder. Ensure that the beam is propagating directly through the waveplate center. If it is not, loosen the base plate and reposition the mount so that it is. Slightly cock the mount off horizontally so that there are no surface reflections from the waveplate propagating back towards the Stretcher setup.

20) Again, remove the waveplate from within its holder.

21) Close reference iris #18 completely. Observe where the beam is relative to the iris center. The iris should be perfectly collapsing upon the propagating beam . If it is not, mechanically adjust the iris both in the X and Y-axis so that it is.

22) Place Pockels cell #17 back into it's mount, in the original orientation that the cell was in prior to commencing the cavity alignment. Resecure the cell back into its holder following the reverse order as stated in step 4A-a-f

Using a white business card, ensure that the beam is propagating directly through the center of both input and output apertures of the Pockels cell. If it appears not to be, one will need to relocate the cell by loosening the two 3/32 balldriver screws securing the mount to the breadboard.

23) Housed inside the Pockels cell is a KD*P crystal. It will be necessary to align the optical axis of the KD*P crystal along the propagating beam. The cell will need to be tilted about two axes to achieve this. (see Fig. 4.2).

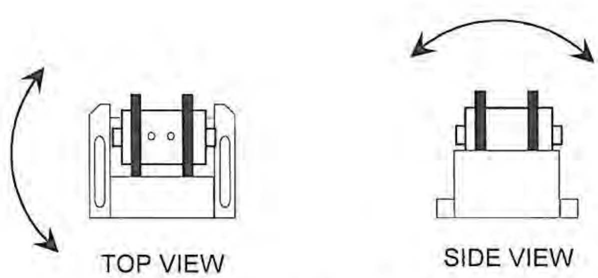

Fig. 4.2 Adjustment for the Pockels cell

24) Place a white business card mid way between component #19 and #17.

25) Place two pieces of cross-polarizing film directly in front of both input and output apertures of the Pockels cell

26) Place a piece of lens tissue between the input aperture of the cell and the polarizer sheet in order to scatter the beam through the cell. Using an infrared viewer, observe the pattern on the white business card.

One should see a pattern as the one shown in Fig. 4.3.

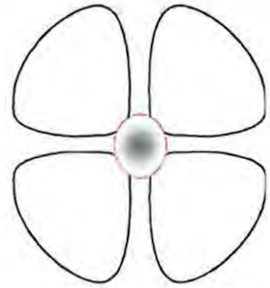

Fig. 4.3 Scattered pattern after the Pockels cell sandwiched between two cross-polarizer if it is aligned correctly.

27) If the observed pattern does not appear to look like the pattern above, an adjustment to the X and/or Y-axis of the Pockels cell mount will be needed (See Fig. 4.4). Use a 1/8-ball driver to make the adjustments.

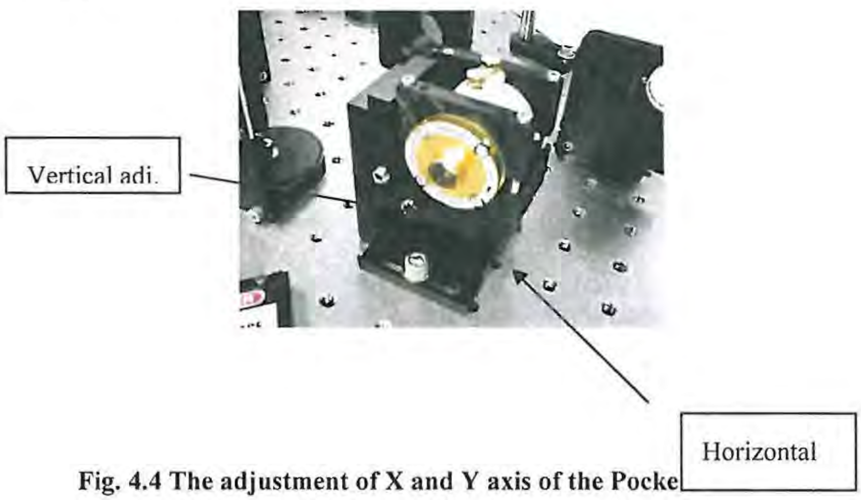

Fig. 4.4 The adjustment of X and Y axis of the Pocke

28) Remove two-polarizer sheets and the lens tissue from around the Pockels cell apertures.

29) Remove the white business card from within the beam path allowing the beam to propagate towards mirror #19.

30) Reinstall the zero degree mirror back into its holder. Secure within its mount using the 1/16 balldriver.

31) Index the Ti:Sapphire rod mount to its present position on the breadboard.

32) Using a 3/32 balldriver, loosen the two screws securing the mount to the bench. Remove and place out and away from its current position.

33) Place the reference block with the cross hair target directly in front of component #21. Check to see that the beam coming from folding mirror #19 is propagating parallel to the bench top at 2.5" above. If it is not, tweak the vertical adjustment of the zero degree mirror #19 so that it is.

34) Place the Ti:Sapphire rod /mount back into its indexed position.

35) Assuming the angle of the Ti:Sapphire rod is correct in its present location, place a piece of lens tissue directly in front of rod side facing component #19.

36) Place a reference block with a white business card tapped or leaning against the block 2-3 inches away, located on the other side of the rod.

37) Using an infrared viewer, observe the pattern created by the lens tissue. One should be able to see the rod aperture relative to the beam propagating through the rod (in this case scattered). If the beam does not appear to be centered, tweak the horizontal adjustment of mirror #19 so that it is.

38) Remove the reference block from within the Regen beam path following the rod.

39) Remove the lens tissue from in front of the other side of the Ti:Sapphire rod.

40) After the beam has propagated through the rod, the beam should strike the inside edge of the second zero degree mirror (component #21), at this time the beam will fold back propagating towards the output panel. The beam should at this time be at 2.5" above the breadboard top.

41) At this time, remove mirror #25 from within its mirror mount.

42) Remove photodiode #41 from its present position.

43) Place the reference block with the crosshair target at 2.5" so that it is located behind the mount corresponding to mirror #25.

44) If the beam from mirror #21 is not striking the reference block at the 2.5" mark, tweak the vertical adjustment of mirror mount so that it is.

45) Collapse fully iris #23. If upon closing the iris, the center of the iris is not collapsing upon the beam, position the height of the iris so that it does so.

46) For the horizontal axis of component #21, tweak it so that the beam is passing through the iris center

47) At this time, using a white business card, observe the passing of the beam through the broadband dielectric polarizer (#22). The beam should be passing through the polarizer center. Use an infrared viewer to verify this. If it does not appear to be, loosen the 3/32 screw securing the mount to the table, and slide the base plate (keeping the mount square to the input/output panel) of the mount vertically until the beam is passing through the center of the component.

48) Resecure the baseplate to the bench.

49) Following the iris, the beam should be propagating through the center of Pockels cell #24. If the beam does not appear to be so, loosen the baseplate screws and slide the mount vertically so that it is.

50) Follow steps 24-26. Set the pitch and yaw (vertical and horizontal axis) of Pockels cell #24 using two polarizer sheets/lens tissue.

51) Place mirror #25 back into its holder and secure by tightening the mount set screw using a 1/16 balldriver.

52) Using an infrared viewer, observe collapsed iris #23. Look for the retro reflection to be propagating from the surface of mirror #25 back to the collapsed iris. If it does not appear to be going back through the iris center, adjust the vertical and horizontal axis of mirror #25 so that it is.

53) Fully open iris #23.

54) Collapse iris #18.

55) Using the infrared viewer, look for the retro reflection from mirror #25 propagating back to the center of iris #18. Make, if any, adjustments to component #25 so that the retro reflection has propagated also through the iris center.

56) Open fully iris #18

57) Insert optic #15 back into its holder.

58) Collapse fully iris # 4.

59) Again using the infrared viewer, look for the retro reflection from mirror #15 propagating back through the stretcher setup towards iris #4 of the Faraday Isolator setup.

This completes the alignment of the Regen cavity.

Pump the Regen cavity with the 527nm-pump beam from the Coherent Pump laser and refer to the procedure "Optimizing the Regen cavity".

4.2 Spectral Improvement

1) Block the seed from propagating into the Regen cavity. Interrupt propagation by closing the mechanical shutter or by blocking the seed into the Regen using a beam block.

2) Use an external turning mirror/mount, and position it between component #29 and the 1"x1" square mirror (#30). Direct the regen output beam into the Spectrometer.

3) Monitor the Q-switch spectrum out of the Regen on the Oscilloscope. It should appear as shown in Fig. 4.5.

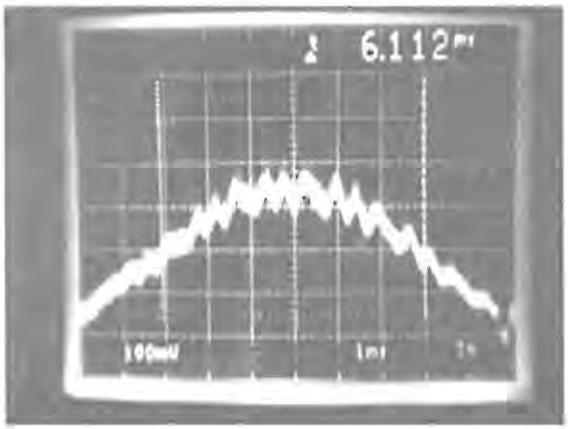

Fig. 4.5 Typical spectrum from Regen cavity

4) The output Spectrum from the Regen should be as smooth as possible although it will never be as smooth as the Seed Oscillator output in comparison.

   Various parameters of the system could induce modulation across the spectrum. In the regen, the various parameters that could potentially modulate the spectrum are:

   a) Misalignment of the Pockels cell(s)

   b) Inappropriate setting of the ¼ waveplate in the Regen

   c) Incorrect ¼ wave voltage to the Pockels cells

4.2.1 Ensuring Modulation Free, "free-running" Spectrum

In order to ensure that all parameters above are optimized correctly, it is best to look at the spectrum in the absences of some of the contributing parameters. To do so, do the following:

1. Disconnect the BNC output cables corresponding to "output 1 and output 2" of the SDG. Doing so allows the triggering of the scope for monitoring the Regen (free-running) intracavity light.
2. In its present position, using a black marker, inscribe a reference mark (if one is not there already) relative to the set-screw securing the ¼ wave plate holder to the mount. Doing so will allow replacement of the wave plate to its original position when one is done.

3. Observe the free-running spectrum on the oscilloscope after removing the wave plate. It should appear as shown in the previous photo. If the spectrum appears to be modulated, a vertical and/or horizontal adjustment to one or both Pockels cell will need to be made depending on how severe either Pockels cells is misarranged. Example of misalignment of the Pockels cell #1 by less than a ¼ turn of a ball driver in the horizontal (yaw) axis can be seen in Fig. 4.6.

4. Tweak the two cells individually such that the spectrum appears the least amount modulated. If gross adjustments are made, it may be necessary to tweak the end mirror corresponding to the Pockels cell that has been adjusted in order to recover the optimization of cavity alignment.

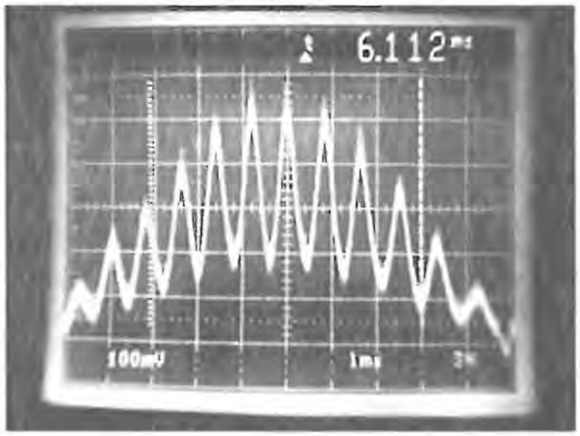

Fig. 4.6 Pockels cell #1 miss-alignment

4.2.2 Ensuring correct orientation of ¼ waveplate and ¼ wave voltage

1) Replace the ¼ waveplate back to its original position as dictated by the inscribed black reference mark.

2) Reconnect the BNC cable to "output 1" enabling the firing of Pockels cell #1.

3) Observe the Q-switch spectrum on the oscilloscope. Ensure that the spectrum is not modulated after insertion of the waveplate into the Regen cavity. If the spectrum appears to be modulated, make slight rotations to the ¼ waveplate with emphasis of smoothing the modulated spectrum. Fig. 4.7 is an example of the Regen spectrum modulated as a function of slight ¼ waveplate misalignment.

Fig. 4.7 Q-Switch spectrum modulated as a function of ¼ waveplate orientation

4) Tweak the potentiometer on the high voltage power supply(HVPS) that varies the high voltage to Pockels cell #1 while observing the Q-switch spectrum. Again it should not be modulated as a function of voltage. If modulated, the spectrum will appear similar to the photo above. Slight tweaks to one or both parameters should ultimately yield a nearly modulated free spectrum.

4.2.3 Observing the Regen spectrum after seeding the Regen cavity

While still observing the Q-switch spectrum (Fig. 4.8), allow the seed beam to propagate into the Regen cavity. In doing so, two things should happen; upon seeding the Regen, the Seed Oscillator spectrum should center itself to the Regen spectrum. Observe this case while monitoring the oscilloscope. If the seeded spectrum does not collapse upon the center of the Regen spectrum, the Seed Oscillator wavelength is offset to the Regen. Tweak the slit of the Seed Oscillator and/or the x-axis of the optical components #14 so that the bandwidth of the seeded spectrum is maximized and central wavelength matched the peak of the unseeded reg. spectrum. (see Fig. 4.9)

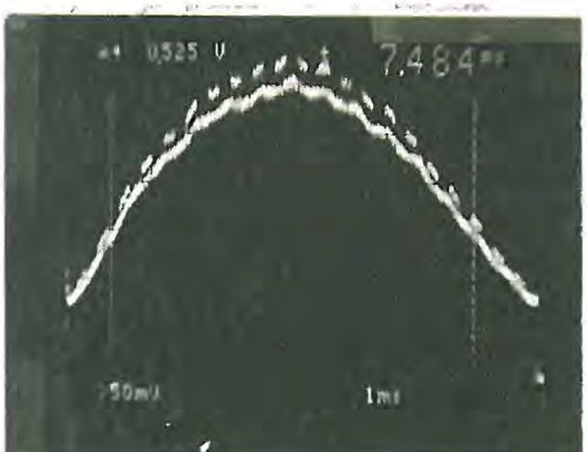

Fig. 4.8 Unseeded reg. Spectrum. (center @ 800nm. Bandwidth =33 nm)

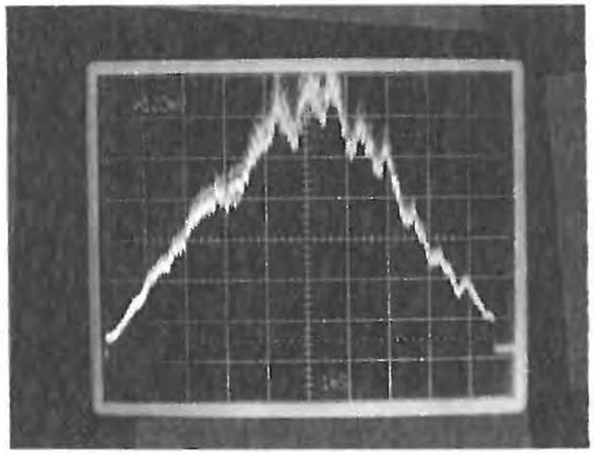

Fig. 4.9 Reg. spectrum after seeding. (center @805nm,Bandwidth = 26 nm)

5 Optimizing Seed Alignment

5.1 First Procedure to Optimize Seed Beam into RA Cavity

1. Following sufficient warm up time, ensure Mai Tai is well mode-locked and performed within system specification.
2. Ensure good performance from the Evolution pump source (i.e.: power and stability).
3. Ensure RA cavity is well optimized in the absence of the seed pulse.
4. Monitor the RA cavity radiation using the Coherent fast photodiode situated behind mirror #25. The typical Q-Switch pulse is shown in Fig. 6.18.

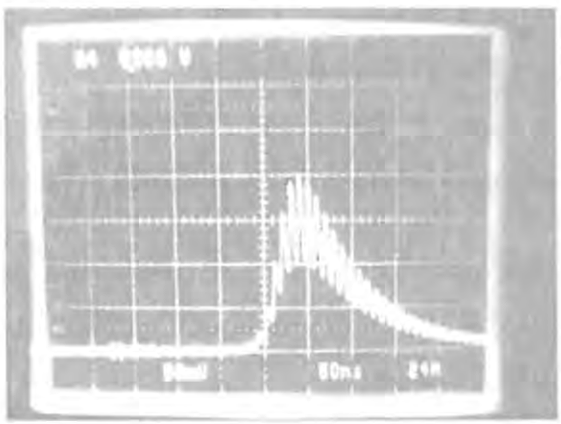

Figure 6.18 RA Cavity Q-Switch pulse

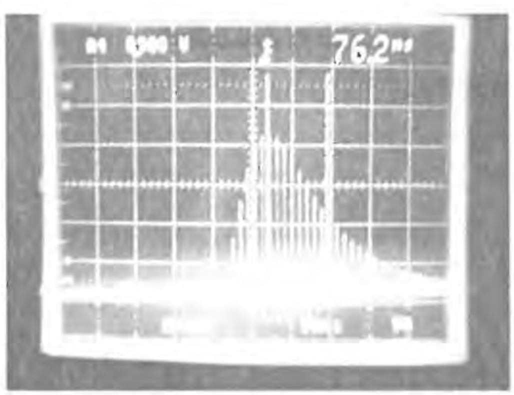

Figure 6.19 RA Cavity "seeded" radiation

5. Delay out the switching time to Pockels cell 2 (#24) so that the SDG digital readout is more than 500ns.
6. Provided that the Mai Tai is optimized and well Mode-locked, allow the beam from the Mai Tai to enter the Legend-F by opening the mechanical shutter of the Mai Tai with computer.
7. If the alignment of the stretched output beam into the RA cavity is optimized, one should see the greatest amount of buildup reduction between the Q-switch signal and the seeding of the Mai Tai pulse into the RA cavity (See Fig. 6.19).

   The difference in buildup between the two conditions is typically >55ns. When this is the case, the seed beam should be "co-linear/superimposed" with the intra-cavity light of the RA.

5.2 Second Procedure to Optimize Seed Beam into RA Cavity

1. Ensure that Steps 1-7 above are satisfactory.
2. Momentarily toggle to the **"off"** position the "**output enable"** switch located on the front panel of the SDG. Doing so will not provide trigger signals to the High Speed Drivers consequently disabling the RA cavity from emitting laser light.
3. Roll out the timing to **"output 2"** such that the digital display indicates 500ns.
4. Take a white card and place it directly in front of component #14 (between components #14 and #15).
5. Using an infrared viewer, locate the "stretched" output beam as it strikes the card.
6. Switch the "**output enable"** switch back to the upward position enabling the firing of the Pockels cell #1.
7. Using the IR viewer, observe where the depolarized light coming from the Ti:Sapphire rod is relative to where the beam from the stretcher is on the card. If the Depolarized light from the rod does not appear to be superimposed upon the stretched output beam, tweak the vertical and/or horizontal axis of mirror #15 so that it does.
8. Move the card from in front of component #15 and place it as close to the rod as possible without interrupting the RA intra-cavity light.
9. Again using the IR viewer, observe where the "stretched' output beam is striking the card relative to where the depolarized light coming from the Ti:Sapphire rod beam is.
10. If the two beams are not super imposed upon one another at this point, tweak the X and/or Y-axis of mirror #14 so that it is.

Warning!

Take great care not to accidentally limit the "stretched" spectrum. The reduced spectrum may cause the damage of the optics in the RA.

11. Continue iterating between steps 4-10 until both beams are superimposed on one another at both locations.

    At this time, the RA cavity should now be "seeded". While observe the buildup reduction on the scope, tweak both the vertical and horizontal adjustments of mirror #14 to finalize the seed alignment.

5.3 Third Procedure for Checking Seed Alignment to RA cavity

1. Ensure that the RA cavity is well optimized in the absence of the seed beam, and the two intra-cavity irises are aligned to the intra-cavity light. (Upon collapsing the iris, its center should symmetrically collapse around the laser cavity light). If this is not the case, reposition the irises in both the X and Y-axis. Check and reposition the two irises one at a time but **ONLY** do so when the RA cavity is optimized in both power and spatial profile.
2. Toggle to the "off" position the **"output enable"** switch located on the front panel of the SDG. Doing so will not provide trigger signals to the High Speed Drivers consequently disabling the RA cavity from emitting laser light.
3. Collapse fully the two intra-cavity irises (#18 and 23)
4. Using an infrared viewer, observe the two iris apertures as the seed beam is allowed to propagate into the RA cavity. The seed beam should be propagating directly through the center. If this is not the case, tweak component #14 to center beam to iris #18 and then tweak mirror #15 so that the seed beam is centered to iris #23. Continue iterating between the two mirrors until the beam is passing through the center simultaneously.
5. Open fully the two irises.
6. Roll out the timing to **"output 2"** such that the digital display indicates 500ns.
7. Switch the **"output enable"** to the upward position.
8. Observe Q-switch radiation from RA cavity using the Coherent photodiode.
9. Allow seed beam to propagate into RA cavity.
10. While observing the buildup reduction make final tweak to the X and Y-axis of mirror #14 while looking for the greatest buildup reduction.

This completes the various procedures for optimizing the seed beam into the RA cavity.

5.4 Cavity Dumping a Pulse

While observing the regen cavity light with the photodiode, roll back the timing via "output 2" of the SDG until the pulse prior to the "main" pulse is seen "cavity dumped" as shown in Fig. 5.3.

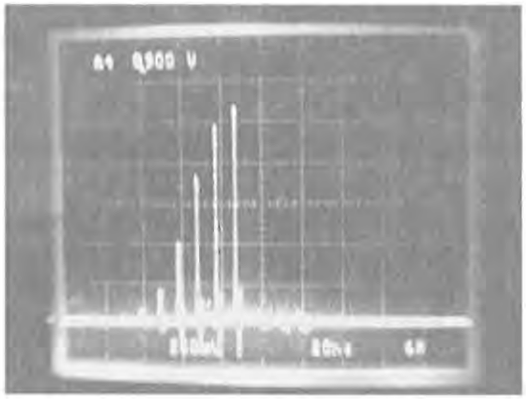

Fig. 5.3 Cavity dumped pulse

6 Compressor Alignment Procedures

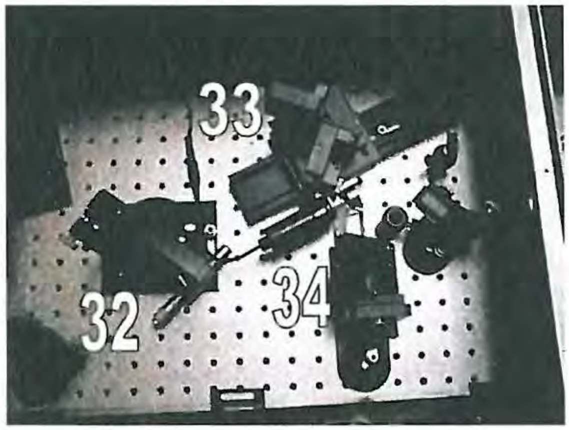

Fig. 6.1 Top view of the compressor

Fig. 6.1 shows the top view of the compressor, which consists of one grating (#32), one horizontal retro-mirror set (#33), and one vertical retro-mirror set (#34). Moving the component #33 back and forth compensates the second order dispersion, and rotating the component #32 compensates higher order dispersion (i.e. 3rd and 4th order). Therefore, by adjusting the components #33, and #32, one should be able to compensates the phase distortions introduced by the stretcher and reg. Amplifier up to the 4th order, and get the shortest pulse duration. Typical pulse duration measured with single shot autocorrelator (SSA) is shown in Fig. 6.2.

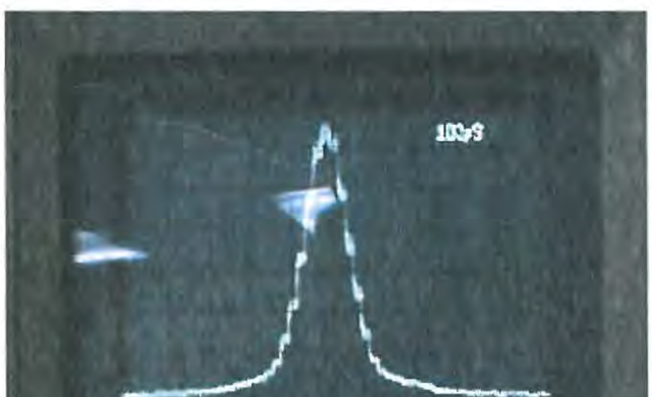

Fig. 6.2 Pulse duration = 40 fsec measured from SSA using Gaussian deconvolution. (Calibration is 44 fsec/100μs before deconvolution)

Before tuning the compressor, one should do the following alignment procedure for the compressor:

1) Close the Pump laser shutter.

2) Disable the Legend-F High Speed Drivers.

3) Close the seed beam input shutter.

Warning: Failure to block the seed beam while performing this part of the procedure will result in major damage to optical components in the regen. This damage is not covered by the warranty.

The unseeded output of the regen is used for the first part of the compressor alignment.

4) Remove the grating assembly as in step 7 of the stretcher alignment procedure.

5) Install the removable reference iris in location #31 and adjust the aperture opening so that it is ~ 4mm.

6) Open the Pump laser shutter.

7) Enable the Legend-F High Speed Drivers and adjust the timing of Pockets cell #2 so there is cavity dumping of the Q-switched pulse.

8) Use mirror #26 to center the beam on the iris at position #31.

9) Disable the High Speed Drivers.

10) Move the iris to position #7. This part is the reverse of the stretcher alignment steps 9-11.

11) Enable the High Speed Drivers.

12) Use mirror #30 to center the beam on the iris.

13) Iterate between steps 5 - 12 until the beam is centered on the iris at both locations.

14) Leave the iris in the #31 location after the beam has been centered at both iris locations.

15) Disable the High Speed Drivers.

16) Close the Pump laser shutter.

17) Install the grating assembly as in step 14 in Section 3, which is the stretcher alignment procedure.

18) Open the seed beam input shutter.

19) Adjust the rotation of the grating assembly so that the stretched beam pattern on the grating appears as shown in Fig. 6.3. Use an IR viewer to verify this.

Stretcher grating

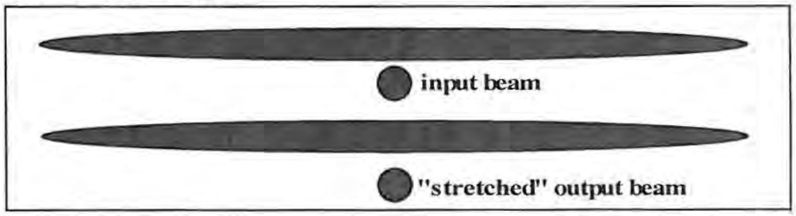

Fig. 6.3 Spatially dispersed spectrum on the stretcher grating

20) Close the seed beam input shutter.

21) Disconnect the trigger BNC for High Speed Driver #2 on the SDG (output 2).

22) Block assemblies #33 and 34.

23) Open the Pump laser shutter.

24) Enable the High Speed Drivers. This will produce a Q-switched pulse.

25) Open the seed beam input shutter. If the seed beam alignment is not optimized for maximum buildup reduction, refer to the procedure "optimizing seed alignment" in Section 5.

26) Connect the trigger BNC cable for High Speed Driver #2 on the SDG and adjust the timing for selecting the proper pulse to be switched out of the Regen cavity.

27) Verify that the seeded regen. output beam is still centered on the iris.

28) Using the IR viewer to look at the grating, one should see a round spot (input beam) on the lower right side of the grating. If the input beam is not on the grating as shown in Fig. 6.4, go back and check the alignment through the iris'.

Note: On chance that the grating has been removed from its mount and put back in, there are reference lines on top of the grating showing how the grating is positioned side to side in the mount

Fig. 6.4 Input beam on the compressor grating

29) Unblock assembly #33 and use IR viewer to look at the grating. One should see the spectrum to the left of the input beam. The spectrum has to be on the same y-axis as the input beam. Use the x-axis screw of assembly #33 so that the input beam and the spectrum are on the same y-axis. See Fig. 6.5.

Do not make adjustments with the y axis screw on mount #33

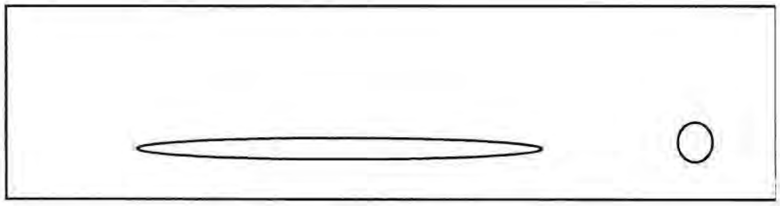

Fig. 6.5 The input beam and the spatially dispersed spectrum by the compressor grating

30) The spectrum should also be centered in the remainder of the grating. See Fig. 6.6. To center the spectrum from side to side on the grating, loosen the 1/4 x 20 screw at the back of assembly #33 and slide the assembly so that the spectrum is centered on the grating.

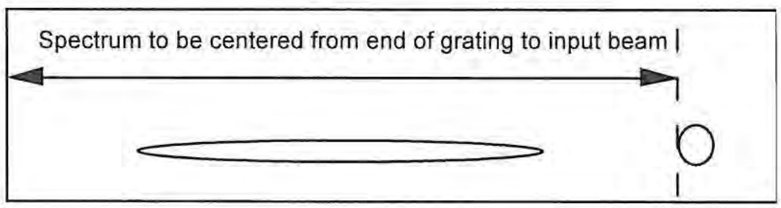

Fig. 6.6 Correct position of the spectrum

31) Unblock assembly #34. Using the IR viewer, one should see the input beam and spectrum on the bottom and the same pattern directly above. See Fig. 6.7.

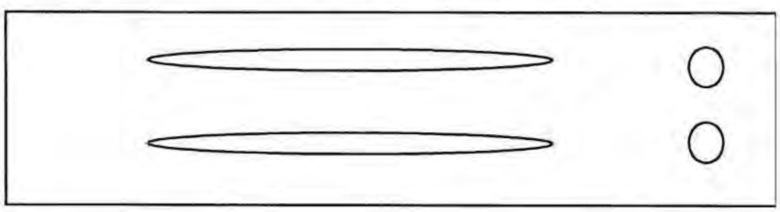

Fig. 6.7 Correct position of the spectrum on the grating after four path through the compressor

32) If the top two beams are not directly above the bottom two beams, the assembly #34 needs to be rotated. Loosen the 1/4 x 20 screw securing the assembly to the breadboard and rotate the entire mount so that the top two beams are directly above the bottom two beams.

Do not make adjustments with the y axis screw on assembly #34

33) The top spectrum and spot should be in the same y-axis. If they are not, adjust the x-axis screw on assembly #34 so that they are on the same y-axis.

34) The top spectrum and output spot are centered on the grating in the space above the bottom beams. See Fig. 6.8. To center the beams, assembly #34 may be moved vertically.

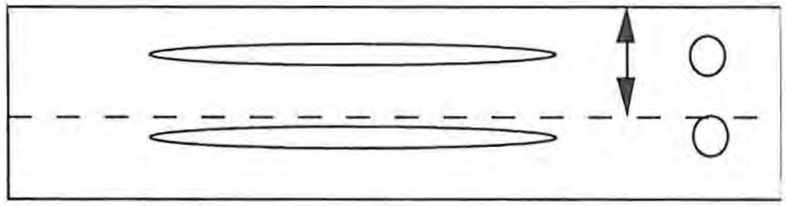

Fig. 6.8 Correct position of the returning spectrum

35) Look at the output beam. There should be no clipping of the beam. Slight adjustments to mirror #34 and mirror #30 may be made if clipping is observed.

36) If adjustments are made with these mirrors, go back and look at the grating with the IR viewer. Verify that the beams are aligned as in Fig. 6.7 and 6.8. If large adjustments are necessary to get rid of any clipping of the output beam then the above procedure needs to be repeated.

7 Replacement Parts

Stretcher			
Component #	**Part #**	**Optical Description**	**Quantity**
1	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 Dg.	1
2	400-0848	Mech. Iris	1
3	799-1753	Ti:Sapphire optical Isolator	1
4	400-0848	Mech. Iris	1
5	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 deg	1
6	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 deg	1
7	400-0848	Mech. Iris	1
8	710-2513	Spectragon. Grating, 30x110x16mm, 1200ln/mm	1
9	705-3447	Mirror, 6" dia, f = 36" Reflective gold	1
10	705-4673	1"x7" Dielectric HR,750-900nm,0 deg.	1
11	705-2528	1"x3" Dielectric HR,750-900nm,45 deg.	2
12	705-2526	1"x1" Dielectric HR,750-900nm,45 deg.	1
13	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 deg	2
14	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 deg	1

Regen Amplifier Cavity			
15	703-3641	CVI mirror, +90cm HR, 0 deg.	1
16	709-2215	1/4 Waveplate, 0 order QWPO-825-05-4	1
17	712-0793	Sol Gel Pockels Cell, 700-1000nm	1
18	400-0848	Mech. Iris	1
19	705-2176	Dielectric HR mirror, 750-900nm, 1" 0 deg	1
20	711-0750	1/4" x1" Ti:Sapphire rod	1
21	705-2176	Dielectric HR mirror, 750-900nm, 1" 0 deg	1
22	708-0795	Kimetic BB polarizer, TFPK,528-RW-28	1
23	400-0848	Mech. Iris	1
24	712-0793	Sol Gel Pockels Cell, 700-1000nm	1
25	703-3641	CVI mirror, +90cm HR, 0 deg.	1

Telescope (8x)			
26	705-2176	Dielectric HR mirror, 750-900nm, 1" 0 deg	1
27	702-3649	Lens, -50mm, BB, KPC040 AR.16	1
28	701-0818	Lens, +400mm, BB, KPX115-AR.16	1
29	705-2527	Dielectric HR mirror, 750-900nm, 1" 45 dig	2

Compressor			
30	705-2526	1"x1" Dielectric HR,750-900nm,45 dig.	1
31	400-0848	Mech. Iris	1
32	710-4735	Richardson Grating, 30x110x16mm, 1500ln/mm	1
33	705-4385	1.5"x3" Dielectric HR,750-900nm,45 deg.	1
33.5	705-4734	1.5"x2" Dielectric HR,750-900nm,45 deg.	1
34	705-2528	1"x3" Dielectric HR,750-900nm,45 deg.	2

8 Customer Service

At Coherent, we take pride in the durability of our products. We place considerable emphasis on controlled manufacturing methods and quality control. Nevertheless, even the finest instruments need occasional service.

8.1 Warranty

Coherent warrants to the original purchaser that the equipment is free from defects in material or workmanship. Coherent will, without charge, make any necessary repairs or replacement of parts to remedy such defect within one year, or 90 days in the case of optical surfaces, provided that Coherent in writing of the nature of such defect within one year, or 90 days for optical surfaces, following the date of original sale of the equipment. The foregoing warranty does not cover equipment that has been damaged by accident or improper use. Coherent does not assume any liability if adaptations are made or accessories attached to the equipment that impair or alter the normal functioning of the equipment. Any repair or adjustment by persons not expressly authorized by Coherent shall relieve Coherent of all obligations. The limited warranty and remedy contained in this paragraph are the only warranty and remedy pertaining to the equipment. COHERENT DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WARRANTY OR MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Coherent shall in no event be liable for any incidental, consequential or other damages or costs, lost profits or inconvenience occasioned by loss of the use of the equipment or labor expended by persons not so authorized by Coherent.

8.2 Return of the Instrument for Repair

Contact your nearest Coherent field sales office, service center, or local distributor for shipping instructions or an on-site service appointment. You are responsible for one-way shipment of the defective part or instrument to Coherent.

We encourage you to use the original shipping boxes during shipment. If shipping boxes have been destroyed or lost, we recommend you order new ones. We can return instruments only in Coherent containers.

MANUAL ADDENDUM

HIGH-ENERGY VERSION

LEGEND-HE

Preface

Copyright

Disclaimer

This manual provides information regarding the operation and maintenance of the Coherent Legend-HE.

Every effort has been made to ensure that the information in this manual is accurate. All information in this document is subject to change without notice. Coherent makes no representation or warranty, either express or implied with respect to this document. In no event will Coherent be liable for any direct, indirect, special, incidental or consequential damages resulting from any defects in this documentation.

Coherent personnel will install the laser system. We do not guarantee laser performance unless the laser is installed by Coherent personnel or by an authorized representative of Coherent.

Support Needs

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1 System Description

1.1 Introduction

Congratulations on your purchase of the Legend-F-HE. The Legend-F-HE is a high-energy, kilohertz rep-rate, Ti:Sapphire regenerative amplifier with a stretcher and compressor, high speed synchronization electronics, and computer-controlled electronics to provide thermal management of the Ti:Sapphire laser rod.

This manual addendum describes the features and operation of the components of the Legend-F-HE that differ from a standard Legend, specifically the Environmental Control Unit (ECU), the control software for the ECU, and the layout of the regenerative amplifier (regen). For the setup and operation of the rest of your Legend system, please refer to the standard Legend manual.

1.2 Theory of Operation

The Legend-F-HE differs from a standard Legend in two main areas: the regenerative amplifier design and the thermal management of the Ti:Sapphire laser rod. The regen cavity design, based on the compact z-fold cavity common to most Legends, has been optimized for efficiency and stability in high pulse energy performance. The Ti:Sapphire rod is pumped from both sizes by a single, high-power Evolution pump laser. The two pump beams are precisely aligned and focused in the Ti:Sapphire rod to match the lasing mode defined by the regen cavity.

To compensate for the increased heat load in the Ti:Sapphire rod due to the high pump power, the rod assembly is actively cooled by a thermoelectric cooler (TEC). The temperature of the rod assembly is monitored through an embedded RTD sensor, and the temperature is regulated to maintain optimum performance, typically in the range of 0-5° C. The hot side of the TEC is regulated by contact with a water-cooled copper heat sink which contains an embedded thermistor temperature sensor.

To prevent condensation at low operating temperatures, the top of the rod assembly is enclosed in a sealed housing with dry air continuously circulated through this housing. Brewster-angle windows are attached at both ends of the housing to transmit the regen and pump beams. The housing also contains a humidity sensor to detect whether the air inside the housing is adequately dry to prevent condensation at the operating temperature of the Ti:Sapphire rod.

The ECU comprises hardware and software that enable the temperature of the Ti:Sapphire rod in your Legend-F-HEto be controlled automatically in conjunction with the operation of the Evolution pump laser. The temperature control circuit includes a commercial temperature controller (Watlow 96) for adjustment of the temperature set-point and monitoring of the Ti:Sapphire temperature. The temperature controller monitors the RTD in the rod assembly and sends a control signal to the power supply for the TEC to regulate the temperature. The ECU also includes interlock electronics monitor the humidity sensor and the thermistor in the cooled copper heat-sink. The interlocks prevent the operation of the TEC if there is high humidity in the laser rod housing or if the temperature of the heat sink exceeds a safe operating temperature. The ECU also contains a small air pump and two desiccant cartridges that supply dry air to the laser rod housing.

The temperature regulating functions of the ECU can be controlled by computer through a USB interface on the front panel of the ECU. The pre-installed software for the Legend-F-HE enables the user to set and monitor the temperature of the laser rod. The software also works in conjunction with the Evolution control software to change the laser rod temperature based on the operating state of the Evolution.

1.3 System Layout

The standard component layout for a typical Legend-F-HE system, including the Evolution pump laser, Mira seed oscillator, and Verdi pump laser, is shown in Figure 1.

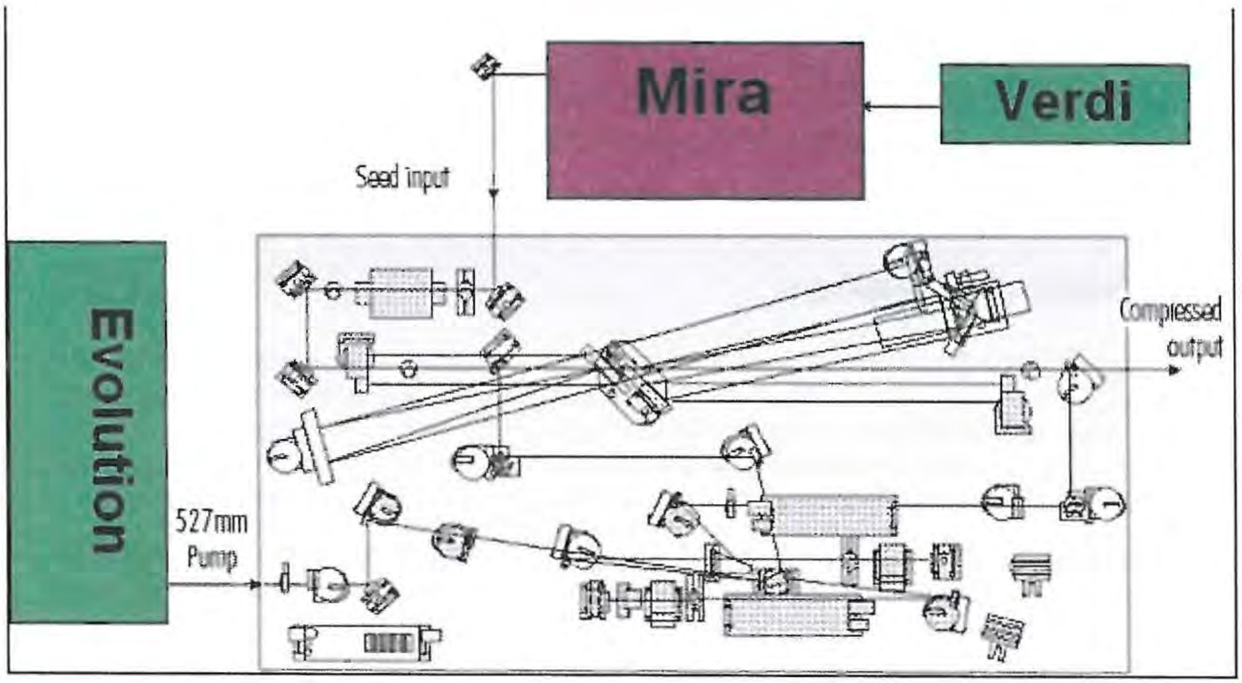

Figure 1: Standard optical layout for a Legend-F-HE system with an Evolution-30 pump and Verdi-pumped Mira seed laser.

1.4 Regenerative Amplifier

The optical layout of the regenerative amplifier is shown in Figure 2. The Evolution pump beam is expanded and collimated by a telescope and then split 50/50 by a dielectric beam splitter. Each pump beam is aligned and focused into each side of the Ti:Sapphire rod. The seed light from the stretcher is reflected from one of the Brewster windows mounted on the laser rod housing.

Refer to the standard Legend manual for a detailed explanation of the other components of the regenerative amplifier.

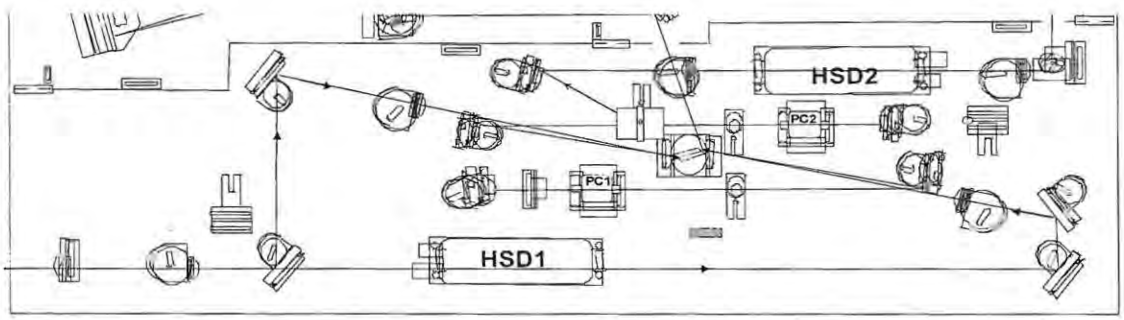

Figure 2: Optical layout of the Legend-F-HE regenerative amplifier.

1.5 ECU

The ECU electronics are contained in a 3U rack-mount enclosure (Figure 3) designed to be mounted in the same rack as the Evolution power supply.

Front panel connections:

- **POWER LED** – illuminates when the ECU power is on.
- **HUMIDITY FAULT LED** – illuminates if there is a high-humidity interlock condition in the laser rod housing.
- **CHILLER FAULT LED** – illuminates if there is a high temperature interlock condition in the water-cooled heat sink (e.g. if the chiller is turned off when the TEC is cooling).
- **USB** – A-type female connection for connecting to the control computer using the supplied USB A-male to A-male cable.
- **TE COOLER CONTROL** – front panel display of the Watlow temperature controller. The top display in green shows the measured temperature of the laser rod mount; the bottom display in red shows the set-point temperature.

Back panel connections:

- **OUT & RETURN** – Quick-connect supply and return fittings for the dry air loop.
- **TEC** – Hybrid D-sub electrical connector to connect to the side-panel of the Legend-F-HEusing the included umbilical.
- On/Off switch for the ECU with an integrated fuse and IEC-320-C14 power connector inlet.

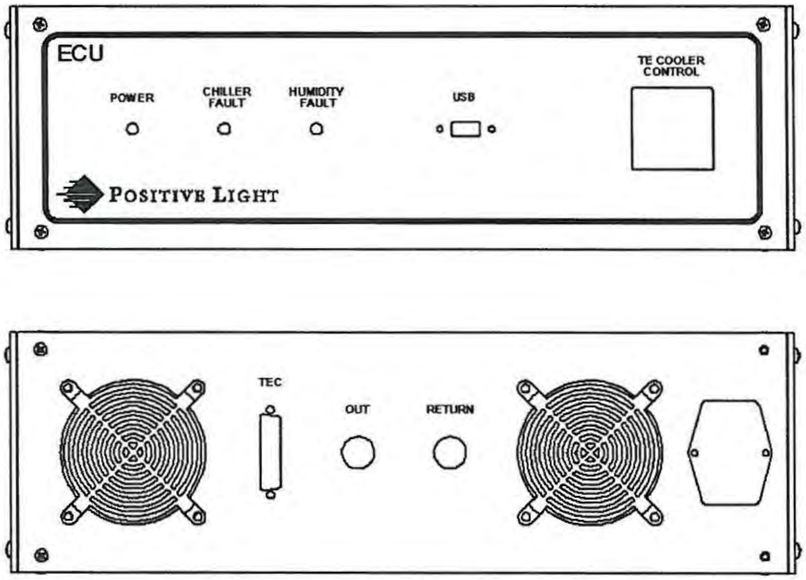

Figure 3: Front- and back-panel of the ECU.

1.6 Software Control

The Legend-F-HE control software includes a window running a version of the Evolution control software (refer to the Evolution manual for a description of these controls) and a window running the ECU control panel shown in Figure 4.

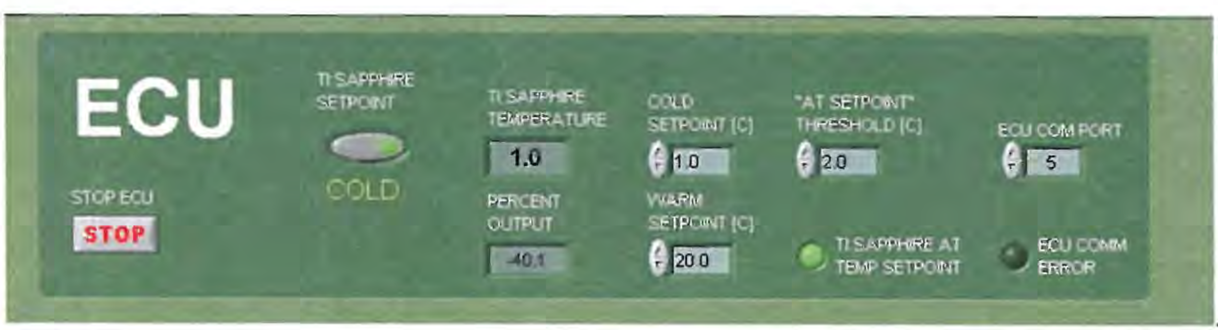

Figure 4: ECU control panel in Legend-F-HE control software.

The controls for the ECU software are:

- **STOP ECU** – Button to stop the ECU software and save the changes made to the other settings.
- **TI:SAPPHIRE SETPOINT** – Toggle switch control to change the setting of the ECU temperature controller between a the Cold set-point and the Warm set-point. Note that when the Evolution control software is running, the state of this control is determined by whether the Evolution is lasing (Cold set-point) or not lasing (Warm set-point). Evolution software is stopped, the user can toggle the set-points.

- **TI:SAPPHIRE TEMPERATURE** – Indicator showing the temperature of the Ti:Sapphire laser rod mount as detected by the ECU temperature controller. Units are degrees Celsius.
- **PERCENT OUTPUT** – Indicator showing the percentage of maximum output power of the TEC power supply. The range is 0 to -90.
- **COLD SETPOINT [C]** – Control for the set-point of the laser rod temperature when the set-point switch is in the 'Cold' position. Units are degrees Celsius, and typical values for this parameter are 0 to 5.
- **WARM SETPOINT [C]** – Control for the set-point of the laser rod temperature when the set-point switch is in the 'Warm' position. Units are degrees Celsius, and typical values for this parameter are 20 to 25, usually the same as the set-point of the Evolution water chiller.
- **"AT SETPOINT" THRESHOLD [C]** – Control for the threshold difference between the temperature set-point and the actual Ti:Sapphire temperature. When this difference is less than the value set, the "At Set-point" LED illuminates. Units are degrees Celsius, and typical values for this parameter is 2.0. Note that this setting has no effect on the function of the ECU.
- **TI:SAPPHIRE AT TEMP SETPOINT** – LED indicator that illuminates when the difference between the temperature set-point and the actual Ti:Sapphire temperature is less than the "At Setpoint" Threshold. This indicator is meant as a convenience to the user to quickly determine if the Ti:Sapphire is at the proper set-point.
- **ECU COM PORT** – Control to set the communications port associated with the ECU. This is set at the factory and should not be changed.
- **ECU COMM ERROR** – LED indicator that illuminates when there is a communications error between the control laptop and the ECU.

Note that the ECU control software only interacts with the temperature controller in the ECU. The status of the ECU interlocks is not monitored by the ECU software. The settings of the ECU software will be set by the service technician who installs your Legend-F-HE laser. Under normal circumstances there is no need for user interaction with the ECU software except to monitor the performance of the temperature controller in the ECU.

2 Legend-F-HE Operation

2.1 TE Cooled Legend Start-up Procedure

Eyewear Required

Danger! Laser Radiation

> The following procedure will result in a laser beam being emitted from the Legend output port. Ensure all persons in the room are wearing adequate laser eye protection. Ensure that the anticipated beam is terminated.

2.1.1 Short Pulse Oscillator:

1. Turn on the external city water supply if any part of the short pulse oscillator requires so.
2. Turn on the chiller corresponding to the short pulse oscillator if one is required.
3. Initiate the **"turn-on"** procedure for standard operation of the short pulse oscillator as described in the system manual. Allow ample warm-up time following turn on for the oscillator to thermally stabilize. Following ample war-up time, ensure optimum power and wavelength.

2.1.2 Environmental Control Unit (ECU):

1. Turn **"On"** the AC switch located behind the back panel.

2.1.3 Evolution Diode Pump Laser:

1. Turn **"On"** the Chiller AC switch.
2. Initiate the turn on procedure for operating the Evolution laser via the control computer.
3. Depress the Evolution AC switch located on the left side of the front panel of the Power Supply to the **"1"** position. The switch will illuminate following turn on.
4. Turn the key located to the right of the AC circuit beaker clock-wise, to the **"ON"** position.
5. On the control computer, open the program labeled **"Legend-F-HE Control"**
6. Turn on the Positive Light Evolution laser by pressing on the **"ON"** button of the Evolution control software. Doing so will set the ECU to the 'Cold' temperature set-point.

2.1.4 Synchronization Delay Generator (SDG):

1. Turn on the SDG. Ensure that the SDG module switch controlling delay output 1 is off. The corresponding LED is will not be illuminated when in the off position.

Note: if the Tsunami laser is not turned on then the SDG will give a "sync error" indication. By overriding the BWD, the user may operate the regenerative amplifier unseeded with the Tsunami laser turned off and switching the SDG sync enable switch to off.

2.1.5 5 kHz Power Supply (5 kHz systems only):

1. Turn on the external 5 KHz High Speed Driver power supply via the AC circuit breaker located behind the unit.

If the system operation does not work as described above, it may be necessary to follow more detailed procedure described later in the standard Legend manual.

2.2 Legend Shutdown Procedure

1. Stop the Evolution lasing by pressing the red "STOP" button located on the computer screen via the control computer. Doing so will cause the ECU to set the Ti:Sapphire rod temperature to the 'Warm' set-point (e.g. 20 C).
2. Stop the Evolution control software by pressing the "Stop and Save Settings" button.
3. Stop the ECU control software by pressing the "STOP ECU" button.
4. Disable the Evolution power supply by turning the "on/off" key counter-clock-wise to the "OFF" position.
5. Depress the Evolution power supply circuit breaker to the off position "0".
6. Turn "off" the Evolution Chiller.
7. Turn off "OUT 1" on the SDG. This disables the regen from working. It is also good to start the system next time it is to be used with this in the off position.
8. Power "off" the SDG.
9. Power off the "on/off" switch corresponding to the ECU unit.
10. Turn off the **"on/off"** switch corresponding to the 5 kHz, High Speed Driver power supply module (5 kHz systems only).
11. Power down the short pulse oscillator/pump source as described in its system manual.
12. If necessary, replace the Legend external covers on the Legend breadboard.

3 Trouble-Shooting

This chapter contains a general user-troubleshooting guide. It is provided to assist you in isolating some of the problems that might arise while using the system. A complete repair procedure is beyond the scope of this manual. For problems that you cannot solve using this guide, contact your authorized service representative.

3.1 Trouble-Shooting Guide

Use this guide if your Legend-F-HE performance drops unexpectedly. If you try the corrective actions and are unable to bring your Evolution-15 performance up to specification, call your authorized service representative for assistance.

Symptom: Ti:Sapphire rod will not reach set-point temperature	
Possible Causes	***Corrective Action***
Humidity interlock	Trouble-shoot humidity fault (see below).
Temperature interlock	Trouble-shoot temperature fault (see below)
Water temperature set incorrectly	Ensure that the water chiller temperature is set to its factory value (typically 20 C).
Pump laser power set too high	Ensure that the Evolution pump laser is operating at the same power level as when the laser was installed.

Symptom: Comm error in control software	
Possible Causes	***Corrective Action***
USB cable unplugged	Stop and close software. Check USB cable connections to the Evolution and ECU. Plug back in if necessary. Restart software.
COM port set incorrectly	Refer to the original values of the COM port settings at the time of installation. Adjust settings as needed.
Evolution or ECU power supply not turned on.	Ensure that both power supplies are turned on before launching the Legend-F-HEsoftware.

Symptom: Humidity interlock illuminated	
Possible Causes	***Corrective Action***
ECU just started up	Wait a few minutes for the ECU to pump dry air through the laser rod housing.
Air hoses disconnected or kinked	Check quick-connects on back of ECU, check hose-barbs on side panel of Legend-F-HEand on laser rod assembly.
Air pump not running	Listen for sound of air pump. If ECU is on and pump is not running, contact your service representative for repair.
Desiccant cartridges consumed	Look through window in top of ECU to see if both desiccant cartridges have turned completely pinkish from exposure to moisture. Replace cartridges if necessary.
Humidity sensor disconnected	Check connections at the laser rod assembly.

Symptom: Temperature interlock illuminated	
Possible Causes	***Corrective Action***
Water hoses disconnected or kinked	Check water connections from Evolution to the hose-barbs on side panel of Legend-F-HEand on laser rod assembly.
Water chiller not running	Turn on water chiller.
Temperature sensor disconnected	Check connections at the laser rod assembly.

COHERENT®

USER MANUAL

SDG II

SYNCHRONIZATION AND DELAY GENERATOR

Preface

Copyright

Disclaimer

This manual provides information regarding the operation and maintenance of the Coherent SDG.

Every effort has been made to ensure that the information in this manual is accurate. All information in this document is subject to change without notice. Coherent makes no representation or warranty, either express or implied with respect to this document. In no event will Coherent be liable for any direct, indirect, special, incidental or consequential damages resulting from any defects in this documentation.

Coherent personnel will install the laser system. We do not guarantee laser performance unless the laser is installed by Coherent personnel or by an authorized representative of Coherent.

Support Needs

If you have any technical questions or problems, please contact Coherent:

Coherent, Inc.
5100 Patrick Henry Drive
Santa Clara, CA 95054

Tel: 408.764.4000

Tech.sales@coherentinc.com
www.coherent.com

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Specifications

Inputs (trigger input and RF synchronization)

Trigger Input	TTL compatible, 0-50 kHz
RF Sync	10-100 MHz, > 100 mV peak to peak

Outputs: (one fixed and three variable delays)

Fixed delay	+200 ns (±ns)
Adjustable delays	0 – 1250 ns in 0.25 ns steps
Jitter	< 250 ps with respect to RF cycle
High Voltage	1 kV – 6kV DC for input to HSD (high speed driver)

Table of Contents

Warning Conventions

The following warnings are used throughout this manual to draw attention to situations or procedures that require extra attention. They warn of hazards to your health, damage to equipment, sensitive procedures, and exceptional circumstances.

Warning Conventions

Danger!	Possible injury or hazard to personal safety
Warning!	Possible damage to equipment
Caution!	Warns against or prevents poor performance or error
Note	Exceptional circumstances or special reference
Danger! Laser Radiation	Laser radiation present
Eyewear Required	Safety eyewear required

1 Laser Safety

Caution!

> Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

This safety section should be thoroughly reviewed prior to operating the SDG II described in this manual. Safety precautions contained herein and throughout the manual must be carefully followed to ensure that all personnel who operate or maintain the laser are protected from accidental or unnecessary exposure to laser radiation.

The Coherent SDG II is not a laser and as such does not present a laser hazard. However the SDG II is designed to facilitate the amplification of short laser pulses. Use of the SDG II therefore presents a laser exposure hazard. It is imperative that the user familiarizes himself/herself with all aspects of laser safety. In particular, read the safety section of all the laser manuals provided with equipment you operate or are exposed to.

This safety chapter should not be construed as a substitute for the safety sections in the manuals provided with the lasers you operate. It is intended as an additional guide to laser safety.

1.1 Hazards

Hazards associated with lasers generally fall into the following categories:

- Exposure to laser radiation which may result in damage to the eyes or skin.
- Exposure to chemical hazards such as particulate matter or gaseous substances released as a result of laser material processing, or a by-product of the lasing process itself.
- Electrical hazards generated in the laser power supply or associated circuits.
- Secondary hazards such as:
  1. X-radiation from faulty power supplies
  2. Pressurized lamps, hoses, cylinders, etc.
  3. Pressurized liquids and gasses.

1.2 Optical Safety

The special nature of laser light poses safety hazards not associated with light from conventional sources. All users of lasers must make themselves familiar with the special hazards associated with their operation.

The safe use of the SDG II requires that all users are familiar with its operation. In particular, eye protection should be worn at all times.

The following safety precautions are to be read and observed by anyone working with the SDG II:

- Wear protective eyewear at all times; selection depends on the wavelength and intensity of the radiation, the conditions of use, and the visual function required. Protective eyewear vendors are listed in the *Laser Focus World, Lasers and Optronics,* and *Photonics Spectra* buyer's guides. Consult the ANSI, ACGIH, or OSHA standards listed at the end of this section for guidance.
- Avoid wearing jewelry or other objects that may reflect or scatter the beam while using the laser.
- Use an infrared detector to verify that the laser beam is on or off before working on the laser.
- Observe all safety precautions in the operator's manual.
- Never look directly into the laser beam.
- Set up controlled access areas for laser operation. Operate lasers only in well marked areas with controlled access. Be sure to post appropriate warning signs visible to all.
- The operation of lasers should be under the supervision of qualified personnel only. When not in use, lasers should be shut down completely and made off-limits to unauthorized personnel.
- Limit access to the laser system to persons required to be present.
- Terminate the laser beam.
- Work with the lowest energy consistent with the application.
- Eliminate unnecessary reflections and scattered laser radiation.
- Work in high ambient illumination.
- Maintain experimental setups at low level to prevent inadvertent eye encounter with beams.
- Follow the instructions in this manual.

1.3 Electrical Safety Precautions

- Disconnect main power lines before working on any electrical equipment when it is not necessary for the equipment to be operating.
- Do not short or ground the power supply output. Positive protection against possible hazards requires proper connection of the ground terminal on the power cable, and an adequate external ground. Check these connections at the time of installation, and periodically thereafter.
- Never work on electrical equipment unless there is another person nearby who is familiar with the operation and hazards of the equipment, and who is competent to administer first aid.
- When possible, keep one hand away from the equipment to reduce the danger of current flowing through the body if a live circuit is accidentally touched.
- Always use approved, insulated tools when working on equipment.
- Special measurement techniques are required for this system. Ground references must be selected by a technician who has a complete understanding of the system operation and associated electronics.

1.4 Protective Eye Wear

It is recommended that laser-safe eye wear is worn at all times. See the manual provided with your laser system for guidelines

1.5 Sources of Additional Information

The following are some sources for additional information on laser safety standards and safety equipment and training.

1.5.1 Laser Safety Standards

SAFE USE OF LASERS (Z136.1)
AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)
1430 BROADWAY
NEW YORK, NY 10018
TEL: (212) 354-3300

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)
U.S. DEPARTMENT OF LABOR
200 CONSTITUTION AVENUE N.W.
WASHINGTON, DC 20210

A GUIDE FOR CONTROL OF LASER HAZARDS
AMERICAN CONFERENCE OF GOVER NMENTAL AND INDUSTRIAL HYGIENISTS (ACGIH)
6500 GLENWAY AVENUE, BLDG. D-7
CINCINNATI, OH 45211
TEL: (513) 661-7881

LASER SAFETY GUIDE
LASER INSTITUTE OF AMERICA
12424 RESEARCH PARKWAY, SUITE 130
ORLANDO, FL 32826
TEL: (407) 380-1553

1.5.2 Equipment and Training

LASER FOCUS BUYER'S GUIDE
LASER FOCUS WORLD
ONE TECHNOLOGY PARK DRIVE
P.O. BOX 989
WESTFORD, MA 01886-9938
TEL: (508) 692-0700

PHOTONICS SPECTRA BUYER'S GUIDE
PHOTONICS SPECTRA
BERKSHIRE COMMON
PITTSFIELD, MA 01202-4949
TEL: (413) 499-0514

LASERS AND OPTRONICS BUYER'S GUIDE
LASERS AND OPTRONICS
301 GIBRALTAR DR.
P.O. BOX 650
MORRIS PLAINS, NJ 07950-0650
TEL: (210) 292-5100

2 Product Overview

2.1 Background

Regenerative amplifiers, seeded by low energy laser pulses, are an extremely efficient means of obtaining high energy, high peak power pulses. The principle of regenerative amplification is to confine, by polarization, a single pulse (selected from a mode-locked train), amplify it to an appropriate energy level, then cavity dump the output. Typically an input pulse of energy only a few nanojoules can be amplified to over 1mJ in a single Ti:Sapphire laser rod, for example. This represents an overall amplification of greater than 10^6. The amplification takes place as the optical pulse passes through the laser rod, which has been optically excited. Normally the amplification of the laser rod is small, only about 3-4 in single pass, however the regenerative amplification technique enables the pulse to multipass the rod resulting in a much higher overall gain.

The amplification of short laser pulses is dependent upon proper timing between the seed-source pulse train operating at many MHz and the amplifier resonator typically pumped at 1-5 kHz. Proper timing can only be facilitated by precisely controlled fast electronics. The SDG II is designed to control the timing between a mode-locked seed source and an amplifier. In a typical configuration a SDG II enables synchronization between the output of a mode-locked laser and a Q-switch driver (HSD). This is accomplished by coupling the RF pulse of the laser mode-locker to the SDG II. Similarly the output of a fast photodiode can be coupled (detecting the pulse train of the mode-locked laser) to the SDG II. The input is synchronized precisely to the RF signal by high-speed electronics. Following synchronization, four delayed trigger signals are produced: one fixed and three user-adjustable in 250 ps steps. Typically, two of these are used to trigger Pockels cell drivers and the other(s) is/are used to trigger a pump-laser Q-switch or oscilloscope. An additional feature is an integrated countdown circuit that allows the experimenter to adjust the output repetition rate to values below the master input rate. The SDG II module is microprocessor controlled, and all delays are digitally displayed and accessible via front panel knobs and a rear panel RS-232 connection.

A prerequisite of regenerative amplifiers is the switching of the Pockels cells at the correct timing - an error of only two or three nanoseconds will result in multiple output pulses. Hence the timing associated with firing the Pockels cells is critical. In a regenerative amplification system alluded to above the first Pockels cell switches the pulse into the resonator. In order to ensure a single pulse is admitted to the resonator, the Pockels cells must be switched at the same time, with respect to the mode-locked pulse train (the seed pulses), every time. To achieve this, switching is synchronized to the RF signal generated by the mode-locker of the seed laser. Additionally, the phase of the switching (the time at which the Pockels cells switch with respect to the pulse train) must be adjustable. Following synchronization, there is a 0-200ns delay that allows phase adjustment. The synchronization electronics and phase adjustment are contained in SDG II module. The SDG II module is triggered by a TTL positive edge pulse that must be provided by the user. The SDG II then produces separate triggers, with adjustable delays, to the Pockels cells. The second Pockels cell switches the pulse out of the resonator. The pulse must be ejected after sufficient round trips and so a delay of approximately 200ns is required after the first Pockels cell switches. There are two adjustable delay adjustments on the timing electronics - the first provides a trigger to PC1, and the second provides a trigger to PC2.

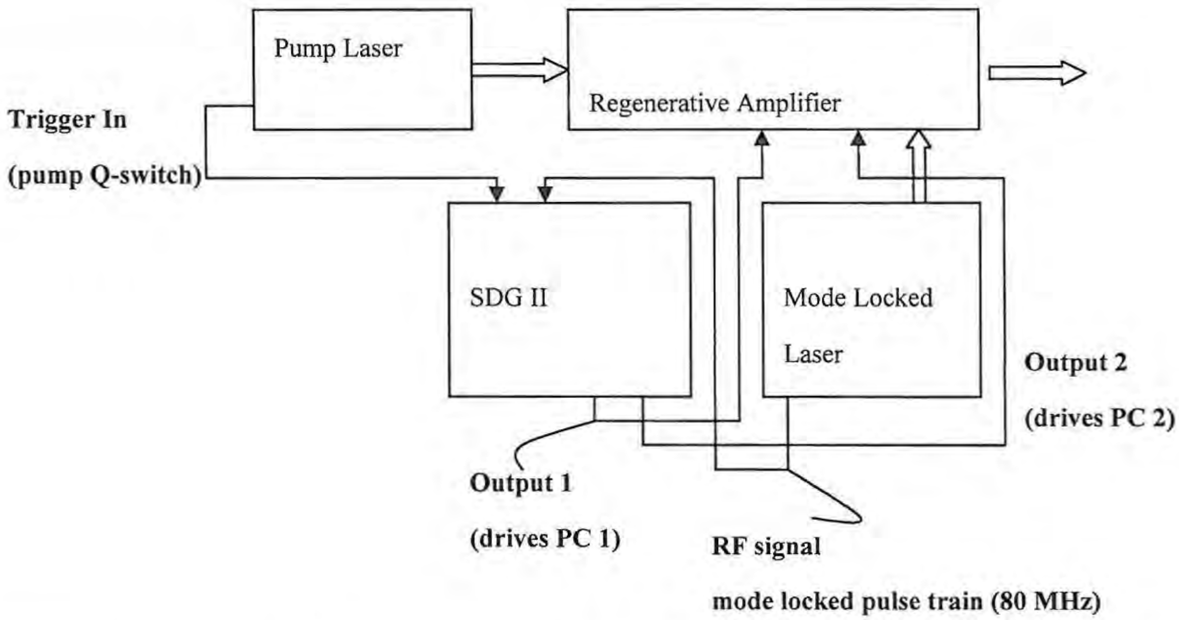
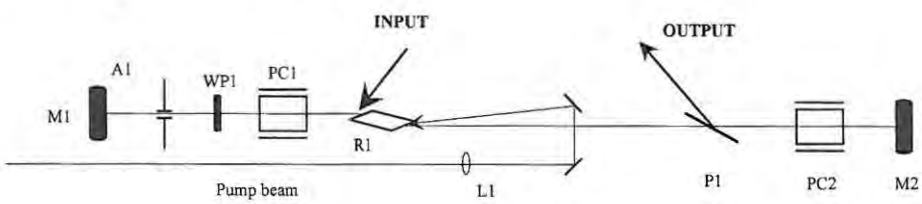


Figure 2.1 shows a typical amplification system. A pump laser provides energy to a cw mode-locked Ti:Sapphire oscillator, which produces approximately 500mW of ultrashort pulses. These pulses are directed to the regenerative amplifier to be stretched, amplified and then recompressed. The regenerative amplifier is pumped with a frequency doubled Nd:YAG or Nd:YLF laser.

A typical optical arrangement is illustrated below:



M1, M2	Resonator end mirror	A1	Aperture
PC1	Input Pockels cell.	P1	Output polarizer
WP1	Quarter-wave plate.	PC2	Output Pockels cell.
R1	Ti:Sapphire laser rod.	L1	Pump beam focusing lens

Figure 2.2: Optical components of a typical amplifier system

Operation is as follows:

1. The pulses from the pulse stretcher are directed into the regenerative amplifier laser cavity.
2. The mode-locked pulses are injected into the regenerative amplifier by reflection off the laser rod (R1).
3. While the input Pockels cell is deactivated, the pulses make a single round-trip through the Legend and exit again, receiving little or no amplification.
4. The pump laser Q-switch is activated providing a pump pulse to the Ti:Sapphire laser rod. This is the time when the Pockels cell, PC1, is activated to begin the amplification process.

We now consider the pulse that will be amplified:

5. The pulse enters the resonator by reflection off the laser rod.
6. The pulse passes through $\lambda/4$ plate and Pockels cell, which is off. It is reflected by mirror M1 and thus retraces its path. Because it has double passed the wave plate it has undergone a $\lambda/2$ rotation and is transmitted by the laser rod and the other resonator optics.
7. As soon as the pulse leaves Pockels cell PC1, quarter-wave voltage (3500V) is applied to it. The Pockels cell is now effectively a $\lambda/4$ plate and so negates the effect of the wave-plate. The pulse is trapped in the resonator.
8. After a number of round trips, usually about 20, a quarter-wave voltage is applied to the output Pockels cell, causing a half wave rotation to the pulse after it has double passed the Pockels cell. The pulse is thus ejected from the resonator by the polarizer. While trapped in the resonator the pulse has multipassed the rod and experienced a gain of over 10^6.

It is important to note that there are various schemes for switching pulse in and out of regenerative amplifier resonators. The primary difference is the number of Pockels cells used - either one or two. Both methods have their merits, at Coherentwe normally use two Pockels cells in our regenerative amplifiers, one to switch the pulse in, the other to switch it out, as described above. However each method requires two well-defined trigger signals, which the SDG II will provide (see figure 2.3).

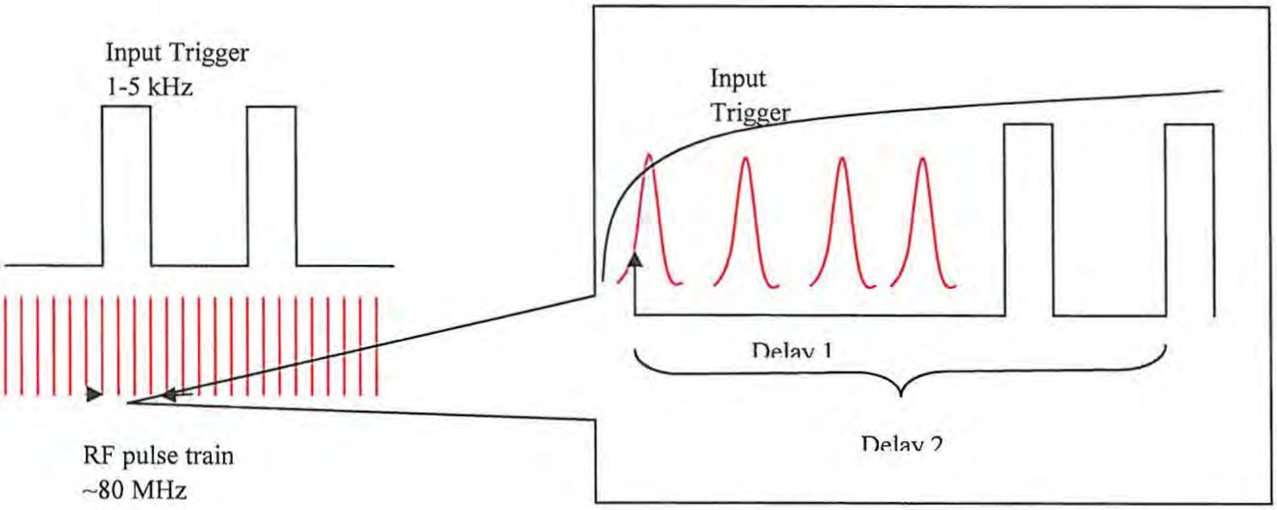


Figure 2.3: Schematic representing synchronization between the RF signal (red) originating form the mode-locked seeding laser and the outputs of the SDG II (delays 1 and 2). These outputs trigger Pockels cells 1 and 2 within the amplifier cavity respectively, switching in a single pulse (via delay 1), and following amplification, switching out a single pulse (via delay 2). Note: *Coordinate(s) not to scale.*

3 Set-up and Operation

Danger! Laser Radiation

Laser radiation present

Eyewear Required

Safety eyewear required

3.1 SDG II Set-up and Connections

3.1.1 Voltage Selection

Normally the SDG II is shipped configured for use with 100 - 120 volt line. If the unit is shipped to a country where typical line voltage is 200 - 240 volts, then the SDG II will be set-up at Coherentto be compatible with this voltage. In this event the ac line port, on the rear of the SDG II, will be marked "200 - 220 Volt Operation". If it is not marked in this manner, you must ensure that your SDG II is set-up for operation at the correct input voltage.

To check the line voltage selection:

1. Disconnect the line voltage from the SDG II.
2. Remove the cover.
3. Close to the two transformers, at the rear right of the unit there are jumpers marked J25 through J28. The silk-screen on the printed circuit card indicates the position of the jumpers required depending on the input voltage.
4. Insure the jumpers are in the correct position to be compatible with the line voltage in your laboratory.
5. Replace the cover.

As already stated the SDG II provides 3 adjustable delay outputs and 1 fixed output that corresponds to the EXT TRIGGER in frequency. These outputs can also be synchronized with an RF signal from a mode locked laser or photodiode, also the output frequency can be divided by factors of 2,5,10 (see description below).

In order to connect the SDG II to your laser follow these instructions:

1. Connect a BNC cable from the output trigger of the pump laser to the input BNC on the SDG II labeled "Trigger In". When using a Coherent"Evolution X" laser to pump your regenerative amplifier then connect the BNC on the rear panel of the Evolution X laser power supply marked "Sync" to the input BNC on the SDG II labeled "Trigger In".

2. Connect a BNC cable from the mode-locker “Sync” or “RF out” to the SDG II "RF Sync" BNC socket.

The other connections on the SDG II rear panel are not necessary for normal operation. Their function is described below.

1. Connect a BNC cable between the "Output 1” on the SDG II and the BNC connector on the first Pockels cell driver in your regenerative amplifier.
2. Connect a BNC cable between the "Output 2" on the SDG II and the BNC connector on the second Pockels cell driver in your regenerative amplifier.
3. The SDG II is now connected for regenerative amplifier operation. Refer to the appropriate section of the manual for optimization of the adjustable outputs for regenerative amplification.

3.1.2 Set-up for Photodiode Synchronization

Normally it is possible to operate the SDG II by synchronizing to the RF output of the mode-locked laser. In some cases however, for example when used with a passively mode-locked laser, this signal is unavailable. In this case it is necessary to use a photodiode to as the source for the synchronization signal.

This path conditions the signal via a 50 Ohm termination. This termination can be switched on by removing the jumpers from the circuit board (labeled “50 Ohm Term. RF”) on the circuit board inside the SDG II near the “RF sync” BNC connector.

It is necessary to “pick off” some of the light from the mode-locked laser beam. Place a fast photodiode on this beam. The photodiode will produce an output that is a megahertz pulse train, similar to the mode-locked laser optical output of course. First, look at this signal on a fast oscilloscope, 300MHz or faster. Ensure that the signal level, *when viewed into a 50 ohm termination*, is 300mV or greater.

3.2 SDG II Detailed Description

3.2.1 SDG II Options

The SDG II has a "+ 5 VDC Enable" on the back which can be connected to an interlock, for example, so that when the interlock is tripped, the output of the regenerative amplifier is disabled by interrupting the triggers to the Pockels cells.

Another option available with the SDG II is to synchronize the Oscillator (or mode-locked laser you are using as a seed source) with a photodiode rather than the RF source provided by the Oscillator electronics. This is useful so that if the Oscillator stops mode locking, the synchronization is disabled since the photodiode will not provide the signal necessary to allow synchronization. If this option is used, then refer the section above.

3.2.2 Front Panel Controls and Connections

Figure 3.1: SDG II Front Panel

TRIGGER FREQUENCY READOUT: Displays the frequency of the SDG II's output indicators.

INPUT DIVIDE: This adjustment allows the operator to divide the output frequency of the SDG II by a factor of 2, 5, and 10.

SYNC ENABLE: This switch selects synchronized or un-synchronized mode of operation, if the LED is illuminated the synchronization is enabled. If the error light is illuminated, then the sync source has been eliminated or the modelocked locked laser has stopped modelocking. Pressing the sync enable button so that the LED turns off will correct the error condition but it will also disable the synchronization portion of the SDG II.

SYNC ERROR: This LED will illuminate when the SDG II is in the synchronized mode and the sync signal is absent.

BWD: This is the bandwidth detection part of the SDG II. The modelocked source beam must be aligned into the stretcher so that the LED's PD 1 and PD 2 can illuminate when the reset button is pressed. Any interruption of the beam alignment in the stretcher will cause either or both LED's to turn off, resulting in the trigger outputs being disabled. Pressing the reset button should return the LED's to their illuminated state. If they do not illuminate, the modelocked source characteristics or alignment have changed. The LED's will illuminate only after the reset button has been pressed; they will not illuminate as a result of a proper alignment of the beam onto the photodiodes without iteratively pressing the reset button. The BWD can be overridden (**not recommended**) by turning the BWD off. The on/off is controlled by a toggle switch on the back panel of the SDG II.

MODE: This allows the user to select between continuous repetition rate firing (based on input trigger) and single shot firing. The illuminated LED indicates the mode of operation.

MAN TRIG: This is the single shot control when the MODE selected in SINGLE SHOT. Pressing this button in this mode will cause the three output triggers to fire a single shot.

ENABLE: These three switches enable or disables the 3 adjustable outputs, it dose not effect the fixed TRIGGER OUT: on the rear panel. If the respective LED's are off, the outputs are disabled and if the LED's are on, the outputs are enabled.

OUT 1 DELAY ns: All adjustable outputs function identically so for simplicity, discussion will be on one output only.

DELAY READOUT: Displays the selected delay in nanoseconds for its corresponding output.

DELAY ADJUST: Adjusts the corresponding outputs delay in 1 ns steps, or 10 ns steps when the adjust knob is pushed in while adjusting. The adjustable range is 0 ns to 1275 ns..

3.2.3 Back Panel Controls and Connections

Figure 3.2: SDG II Rear Panel

INTERLOCK ENABLE: This switch enables or disables the +5VDC connector. In the up position the +5VDC connector is nonfunctional, in the down position the connector is functional.

+5VDC ENABLE: This connection allows the operator to connect an interlock switch to the SDG II that will disable all the adjustable outputs when the switch is open. Grounding the center pin of the BNC will enable operation.

TRIGGER OUT: is a fixed output. The input pulse trigger to the SDG II goes through a one-shot that results in this TRIGGER OUT before the signal is sent to the three adjustable outputs on the front of the SDG II.

EXT TRIGGER: Apply the trigger source to this connector. The trigger source should be 50Ω, TTL

RF SYNC: Apply the synchronization signal to this connector. The rf source should be >100mV, 0-100MHz into 50Ω. A jumper inside of the SDG II should be removed if the rf source is not 50Ω.

BWD ON: the BWD circuit is activated when the 4 pin 12mm connector is connected and the switch is in the up position. The switch in the down position disables the BWD (not recommended).

SERIAL PORT: Allows RS232 connection for control and programming of the SDG II via a computer using ASCII terminal software (see description below).

HIGH VOLTAGE: both HV1 and HV2 are 0-6kV DC outputs. These are connected and used to power both HSD's (High Speed Driver).

110/220 VAC: Fused primary power input for the SDG II, incorporated in this module is EMI protection, 1/2 Amp fuse and an on/off switch.

3.3 SDG II Computer Interface

Most functions of the SDG II can be controlled by any computer with a standard RS-232 serial port. The SDG II command syntax is designed to replicate the functions of the controls and read-outs on the front panel of the SDG II.

3.3.1 RS-232 Connector Wiring

The SDG II serial port accepts a standard 9-pin D-sub male/female extension cable for hookup. Only three pins on the are used for serial communications:

Pin Number	Function
2	SDG II transmit data, computer receive data
3	SDG II receive data, computer transmit data
5	Signal ground

3.3.2 RS-232 Communication Protocols

The SDG II uses the following communication protocols, which must be set accordingly in the communications program used to control the SDG II.

Setting	Value
Rate	9600 bps
Data bits	8
Parity	None
Stop Bits	1
Flow Control	None

3.3.3 Command/Query/Response Format

All SDG II RS-232 commands, queries, and responses are in ASCII format. Each command or query must be terminated with a carriage return <CR>. Commands that have a numerical argument be sent with all of the digits, preceded with zeros if necessary. Commands must be sent in all lowercase. All queries end with a question mark (?). Valid queries return data followed by a carriage return <CR>. Valid commands return the string "Ok". Invalid commands or queries return the string "Bad".

3.3.4 Command Quick Reference

Command	Parameter	Function
status?	none	Returns overall status of SDG II (see below)
set:cN #	0, 1	Enable (1) or disable (0) output on channel N (1-3)
read:cN?	none	Returns the output state of channel N (1-3)
set:del:cN ####.#	0000.0 to 9999.9	Set the delay for channel N (1-3) in ns
read:del:cN?	none	Returns the delay for channel N (1-3) in ns
set:rate ####	0001, 0002, etc.	Sets the trigger rate division factor
read:rate?	none	Returns the trigger rate division factor
read:bwd?	none	Returns the state of the BWD latching interlock
reset:bwd	none	Reset the BWD latching interlock
read:sta:bwd?	none	Read the state of the BWD photodiodes
set:rf #	0, 1	Enable (1) or disable (0) the RF sync
read:rf?	none	Returns the state of the RF sync
set:mode #	0, 1	Set the trigger mode to continuous (0) or single-shot (1)
read:mode?	none	Returns the state of the trigger mode
man:trig	<none>	Manually trigger the SDG II in single-shot mode

3.3.5 Full Command Description

status?

Returns the status of the SDG II as a comma-delimited list of eleven parameters. These values are listed in the following table:

Parameter	# of Characters	Value
Output 1 state	1	0 (OFF) or 1 (ON)
Output 2 state	1	0 (OFF) or 1 (ON)
Sync Out state	1	0 (OFF) or 1 (ON)
Output 1 delay	6	0000.0 ns to 9999.7 ns
Output 2 delay	6	0000.0 ns to 9999.7 ns
Sync Out delay	6	0000.0 ns to 9999.7 ns
Trigger division factor	4	0001 to 0010
BWD Switch state	1	0 (OFF) or 1 (ON)
BWD photodiode & Ext Interlock state	3	000 to 111 (see below under read:sta:bwd?)
Continuous/Single shot	1	0 (continuous) or 1 (single shot)
RF Sync state	1	0 (OFF) or 1 (ON)

set:cN

Sets the output of channel N (N=1 for Out 1, N=2 for Out 2, N=3 for Sync Out) to be enabled (1) or disabled (0).

read:cN?

Read the output state of channel N (N=1 for Out 1, N=2 for Out 2, N=3 for Sync Out) as enabled (1) or disabled (0). The output state is also displayed by corresponding LED on the front panel.

set:del:cN ####.#

Set the delay of channel N (N=1 for Out 1, N=2 for Out 2, N=3 for Sync Out) in nanoseconds (ns). The minimum increment for the SDG II is 0.25 ns. The allowed values for the last digit (after the decimal) are 0, 2, 5, and 7, corresponding to 0.00, 0.25, 0.50, and 0.75 ns respectively. Last digits other that 0,2,5,7 are rounded down to allowed values.

read:del:cN?

Returns the delay setting for channel N (N=1 for Out 1, N=2 for Out 2, N=3 for Sync Out). The allowed values for the last digit (after the decimal) are 0, 2, 5, and 7, corresponding to 0.00, 0.25, 0.50, and 0.75 ns respectively.

set:rate

Sets the factor by which the input trigger frequency (rep rate) is divided to produce the output trigger frequency. Allowed values are 0001, 0002, 0005 and 0010. For example, if the input trigger rep rate is 1.000 kHz, a rate of 0005 will set the output frequency to 0.200 kHz.

read:rate?

Returns the input/output frequency divisor set by the set:rate command.

read:bwd?

Returns the state (0 = off, 1 = on) of the BWD mechanical switch on the back of the SDG II.

reset:bwd

Resets the BWD latching interlock. If the BWD switch is on and both BWD photodiodes (PD 1 and PD 2) are illuminated, reset:bwd will clear the BWD latching interlock. If the BWD switch is off, reset:bwd will clear the BWD latching interlock regardless of the state of the BWD photodiodes.

read:sta:bwd?

Returns a string of three binary values. The first two values are the states of PD 1 and PD 2 (0 = off, 1 = on). The third value is the state of the +5V DC interlock (0 = latched, 1 = clear). For example, "110" indicates that PD 1 and PD 2 are illuminated but the +5V DC interlock is latched, preventing output.

set:rf

Sets the state of the RF sync to be enabled (1) or disabled (0).

read:rf?

Returns the state of the RF sync as enabled (1) or disabled (0).

set:mode #

Sets the output trigger mode to continuous (0) or single-shot (1).

read:mode?

Returns the output trigger mode as continuous (0) or single-shot (1).

man:trig

Executes a single output event when the SDG II is in single-shot mode.

3.3.6 Limitations of RS-232 Control of the SDG II

The following functions of the SDG II cannot currently be accessed with RS-232 commands:

- The value in the Trigger Frequency display cannot be read.
- The status of the Sync Enable Error LED cannot be read.
- The state set by the BWD on/off mechanical switch cannot be changed.
- The state set by the Interlock enable/disable mechanical switch cannot be changed.

3.3.7 Typical Command Usage

The following list gives a simple control flow for the SDG II using RS-232 commands.

1. Turn on the system, then wait >5 seconds for the SDG II in initialize.
2. Issue a *status?* command to determine the state of the SDG II.
3. Enable the required outputs with the *set:cN* commands; set the required delay values with the *set:del:cN* commands; set output trigger frequency with the *set:rate* command.
4. If all interlocks are cleared, issue a *reset:bwd* command to enable output.
5. Monitor the SDG II by periodically issuing a *status?* command.

4 Regenerative Amplifier Alignment

This chapter is provided as a guide to regenerative amplifier alignment and operation. Coherent makes no representation, or warranty as to whether this procedure will be applicable to your amplifier layout. If any damage occurs to your amplifier Coherent is not responsible.

4.1 Static Regenerative Amplifier Alignment

If you have real difficulty getting the regenerative amplifier to lase then, you will have to perform a complete alignment. Do not attempt this procedure before consulting a Coherent or Coherent representative.

1. Set up the helium neon laser and two turning mirrors so that the beam can be aligned down the regenerative amplifier resonator, starting at the second Pockels cell end of the resonator. It is important that the beam is aligned parallel to the optical bench and at a height of 2½ inches above it. This is easily accomplished by partially closing both intra-cavity irises so that the helium neon beam can be referenced to them.
2. The beam should now be centered through each optical element in the resonator. To verify this, place a piece of white paper in front of the optic to be inspected, so as to block the HeNe beam from passing through the optic. Using a small inspection mirror look through the end opposite the paper. If the HeNe spot is close to an edge of the optical surface loosen the optical element mount and center the optic in the beam or refer to following sections which provide more detail for proper alignment of the critical optical elements (Pockels cell, crystal, etc.).
3. If all optical elements appear to be properly aligned, adjust the left-end high reflector to reflect the HeNe beam back along its path through both partially closed irises. Repeat this for the right-end high reflector.
4. Open up both apertures.
5. Follow the procedure described in the "Lasing Optimization" beginning of this chapter to complete the alignment of the regenerative amplifier.

4.1.1 Pockels Cell Alignment

Use white paper to see if the beam is propagating directly through the center of the input and output apertures of the Pockels cell (PC2). If it does not the Pockels cell must relocated.

Housed inside the Pockels cell is a KD*P crystal. It is necessary to align the optic axis of the KD*P crystal along the beam. The cell must be tilted about two axes to achieve this (see below), the Pockels cell mount has these adjustments on it.

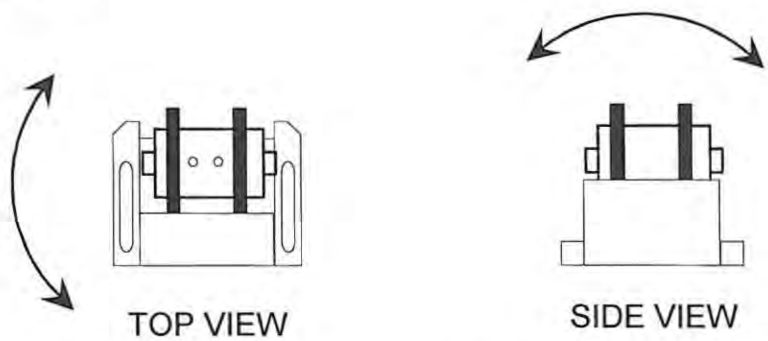


Figure 4.1: Pockels cell adjustments

Use a piece of white paper or card and place it in the beam about 3 inches beyond the Pockels cell so that you can view the beam on it. Place a piece of lens tissue in the beam directly in front of the Pockels cell to scatter the beam through the cell.

It is necessary to view the beam through crossed polarizers. Place a piece of sheet polarizing film in the HeNe beam at any point prior to the Pockels cell. Place a second piece of polarizing film in the beam immediately after the Pockels. You will see a pattern like this on the white paper:

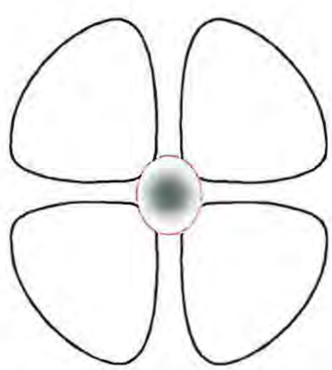


Figure 4.2: HeNe pattern following correctly aligned Pockels cell

The pattern shown above represents a perfectly aligned Pockels cell, the spot in the center being the HeNe beam. You will need to adjust the Pockels cell tilt, in both axes, to center the pattern on the beam.

1. Remove the lens tissue etc. from the beam path.

2. Check the beam height at the end of the resonator (near M2). The Pockels cell may have slightly raised or lowered the beam, if so then readjust the beam.

4.1.2 Polarizer Alignment

1. The thin film polarizer is mounted in a housing which places the polarizer at the correct angle provided that the mount which holds the housing is placed as close to perpendicular to the optical cavity as possible.

2. Look at the HeNe reflection off the polarizer and measure the beam height. If it is not 2.5", loosen the set screw which holds the polarizer housing in the mount and rotate the polarizer housing until the reflection is at 2.5".

3. Verify that the beam passing through the polarizer is not clipped. If it is, loosen the polarizer mount and translate it. Repeat step 1.

4.1.3 Laser Rod Alignment

1. If a crystal requires replacement, remove the two screws holding the top of the crystal mount to the bottom mount and remove the top mount. Carefully remove and replace the crystal. Replace the top mount but do not tighten the screws.

2. Rotate the crystal until the reflected HeNe beam (or low energy pump beam) is at 2.5". Carefully tighten the two top screws making sure the reflection remains at 2.5".

3. The crystal front face is set at Brewster's angle at the factory. As long as the bottom crystal mount assembly has not been adjusted, no realignment should be necessary. If the bottom mount has been rotated then Brewster's angle (60 degrees) should be reset.

4.1.4 Mirror Alignment

1. Make a small hole in the sheet of white paper (about 1-2mm diameter). Place this in the HeNe beam about 1' (30cm) from the first resonator mirror. There should be a back reflection onto the paper that passes directly through the hole. Note that there may be reflections from other surfaces on the resonator that could be deceiving - a white card placed directly between the mirror and pinhole will block these reflections. When the mirror is well aligned the back reflection from the mirror will be difficult to see because it passes through the hole. If the mirror is not well aligned then the back reflection will appear close to the hole. (You will be able to see this best with the lights dimmed). Make small adjustments to the X and Y adjustments to center the back reflection on the hole.

2. Repeat this process for the other resonator mirror. In this case the best position for the paper is between the laser head and the second Pockels cell. There will be several reflections from the polarizer cell which will be confusing. In this case you must determine which is the correct reflection.

3. The static optical alignment is now complete, however it is a good idea to leave the HeNe aligned until you have completed the active alignment.

4.2 Lasing Optimization

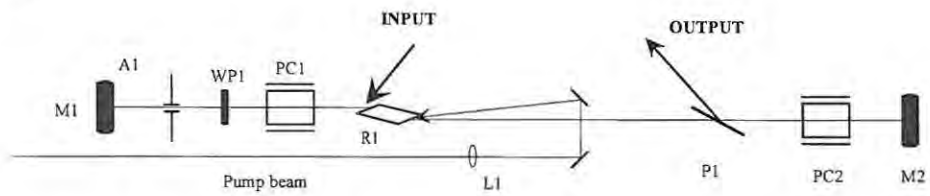
This procedure assumes that the regenerative amplifier oscillator is lasing, but requires complete optimization. If the regenerative amplifier oscillator is not lasing then it may be necessary to follow the static alignment procedure outlined below. Prior to attempted this procedure it is advisable to follow the "Daily Optimization" procedure in the preceding chapter.

Do not attempt to seed the regenerative amplifier with the cw laser beam yet. Operation must be verified as a Q-switched laser first. To do this block the seed beam while completing the procedure below.

WARNING!

All personnel within the laser room must wear laser protective eye wear at all times that the laser is operating. Even small energies from a pulsed laser system can cause permanent eye damage. Goggles should be worn of at least O.D. 4 to all lasing wavelengths.

The regenerative amplifier is a laser which acts as an amplifier when a subnanosecond pulse of intensity greater than the intracavity noise level is injected into the resonator. Hence to ensure alignment of the regenerative amplifier is optimized, the regenerative amplifier can be operated as a laser in the absence of a seed pulse:



M1, M2 Resonator mirror
A1 Aperture
WP1 Broadband waveplate
PC1, PC2 Pockels Cell

R1 Ti:Sapphire Laser Rod
P1 Broadband polarizer
L1 Pump beam lens

Figure 4.3: Optical schematic, regenerative amplifier

1. Turn on the pump laser and check the pump alignment into the Ti:Sapphire crystal.
2. Turn down the lamp energies to minimum.
3. Disconnect the BNC cables from the SDG II "OUT 2" and "OUT 3" to ensure that both Pockels cells are not triggered.
4. Remove the waveplate, WP1, by removing its entire mount as you will need to replace it in the exact same orientation.
5. Slowly bring up the lamp energy to maximum.
6. The laser will begin to lase in the "free-running" mode. If there is no lasing then make small adjustments to mirror M2.
7. Use a photodiode and observe the transmitted lasing, through the resonator mirror, M2 on an oscilloscope. The photodiode should be used with the 1MΩ, 50-100μs/division"
8. The signal should look like this:

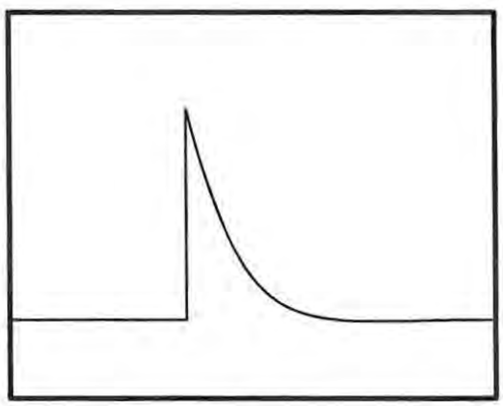


Figure 4.4: Free-running laser pulse

1. Make sure that the signal disappears when the resonator is blocked.
2. Carefully adjust mirror M2 for maximum amplitude of the oscilloscope trace.
3. **Carefully** adjust the pump beam alignment to optimize lasing.
4. Replace waveplate WP1, the signal on the oscilloscope should disappear indicating no lasing.
5. Monitor the photodiode to ensure that no lasing occurs. If there is lasing then try rotating WP1 slightly to eradicate it. Do not make large adjustments.
6. Reconnect the BNC cable to the SDG II "OUT 2" to allow the first Pockels cell to trigger. The laser should now Q-switch.

7. Change the photodiode to a 50Ω input and 50 or 100ns/division. At this time it is best to externally trigger the oscilloscope from the "OUT 1" BNC on the SDG II.

8. The photodiode position should remain the same, looking through mirror M2. You will now see the Q-switched pulse on the oscilloscope. The exact shape of the pulse will vary depending on several factors including pump energy, mode-beating, resonator alignment etc. An example of what it may look like is shown below:

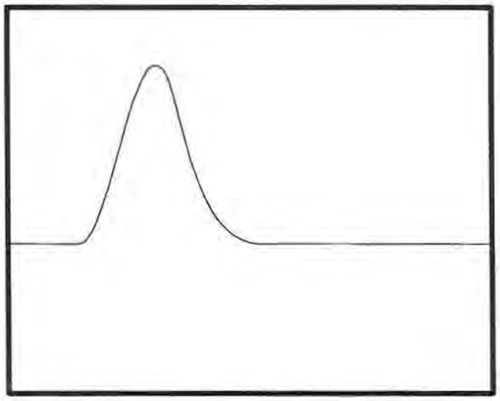


Figure 4.5: Example of Q-switched pulse

1. Adjust the crystal angle on the HG2 to optimize the 532nm energy and in turn, the regenerative amplifier Q-switched energy. This should minimize the build up time, shorten the pulse, and increase its amplitude.

2. Reconnect the BNC cable to the SDG II "OUT 3". This will allow the regenerative amplifier to be cavity dumped by allowing the second Pockels cell to be triggered.

3. If a Q-switched pulse is not present, then turn the SDG II "OUT 3" delay control clockwise until the Q-switched pulse is seen. The intracavity, Q-switched, cavity dumped pulse should look like the figure below. If the Q-switched pulse is present in its usual shape, then turn the delay control counter-clockwise to obtain the shape shown below. Measure the ejected pulse energy. The energy measured Q-switched, cavity dumped will be very close to the energy measured when the regenerative amplifier is seeded and cavity dumped. Verify that the energy measured is the same or close to the energy measured at the time of installation.

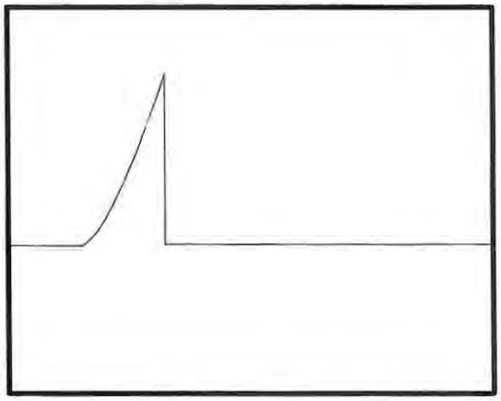


Figure 4.6: Intra-cavity, Q-switched, cavity dumped pulse. (Note - actual pulse shape depends on time at which cavity dumping takes place).

4.3 Seed Alignment

The next step is to align the mode-locked beam (the seed beam) into the regenerative amplifier resonator.

1. Turn off the pump laser. Optimize the mode locked laser performance.
2. Referring to figure 6.11, verify that the seed beam is reflecting off of the mirror (13) before being reflected off of the crystal surface (14) and into the regenerative amplifier resonator.
3. Use mirror (13) and (12) to align the beam through the aperture. Only these two mirror adjustments should be necessary to align or "walk" the seed beam through the regenerative amplifier to mirror (16).

Figure 4.7 (below) shows the seed beam alignment path into the Coherentregenerative amplifier resonator.

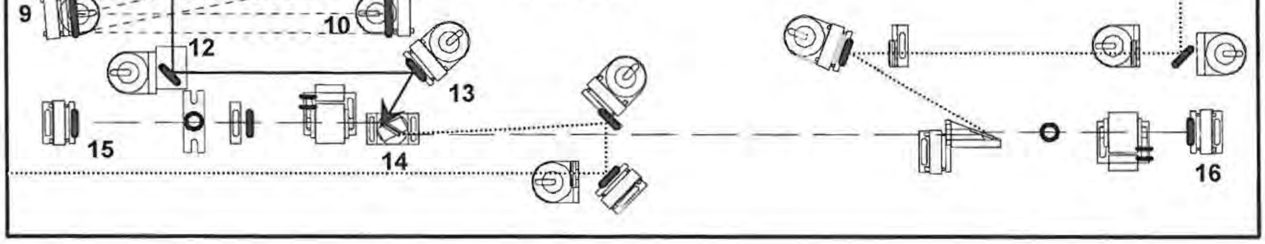


Figure 4.7: Seed beam alignment

The beam path is illustrated above and is as follows:

The input beam is turned 90^{o} by the input mirror (1), through the alignment aperture (2), through the vertical retro assembly (3) and then through the Faraday Isolator (4). It is then directed to the stretcher via alignment mirrors (5) and (6). The beam then passes through the stretcher (7), (8), (9), and (10). The beam is picked off by mirror (11). The beam is directed to the polarization rotator (12) and then into the amplifier via mirror (13) and injected into the resonator by reflection off the face of the Ti:Sapphire laser crystal (14).

An IR card should be used to quickly check the alignment of the cw beam into the regenerative amplifier. The beam is injected into the regenerative amplifier by reflecting off one face of the laser crystal (14). It is likely that the beam will have drifted slightly since the regenerative amplifier was last operated. The beam should be aligned so that it is centered on the pinhole and then on the resonator mirror (15). Enough of the beam should pass through the pinhole to be reflected back down the resonator, through all the optics (including the laser crystal) to the second cavity mirror (16). Use the IR card to ensure that the beam is clearly visible at mirror (16). Make slight adjustments to the input mirror (15), *not* the resonator mirror, until you see a beam at mirror (16). You are now ready to turn on the GCR lamps.

If you cannot see the beam it will be necessary to check the alignment through the stretcher.

4.4 Regenerative Amplification

You are now ready to begin amplifying the input pulses to the regenerative amplifier. If you are uncertain of the steps taken previous to this point, then review and/or repeat those steps if necessary. Please remember that the technical staff of Coherent will be pleased to assist. You are welcome to call or fax your questions.

1. Block the seed beam from entering the regenerative amplifier. Turn on the pump laser to its full operating pump level.
2. Make sure that the SDG II "Sync Enable" switch is in the "up" or "on" position. Disconnect the SDG II "OUT 3" BNC. This disables the triggering of the second Pockels cell. Trigger the oscilloscope externally from the SDG II "OUT 1" BNC.
3. Check the photodiode output on the oscilloscope, you should see the Q-switched pulse that was observed in step 16 of "Lasing Optimization".
4. Unblock the seed beam entering the regenerative amplifier. If the seed beam is well aligned you should see a pulse train on the oscilloscope. Below is an example of what you may see if the timing synchronization is set correctly and the seed alignment is good, but it is unlikely. (The timing synchronization will be adjusted later in this section).

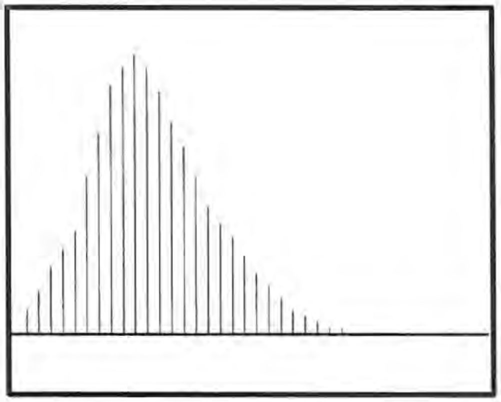


Figure 4.8: Intracavity pulse train

Alternatively, you may see a Q-switched laser pulse with mode locked pulses riding on top of it.

1. Before beginning the rest of the procedure it is important that the oscilloscope is triggered externally from SDG II "OUT 1" BNC.
2. To optimize the cw alignment into the resonator adjust the input steering mirrors into the resonator to minimize the buildup time of the pulse train while maximizing the amplitude of the earliest pulses. These are the same steering mirrors used in step 4 of "Seed Alignment".
3. Once the alignment of the seed beam is optimized you will see a pulse train that looks like that above. If you cannot achieve a pulse train like that above then make ***small*** adjustments to the SDG II "OUT 2 " delay control to optimize the timing synchronization. This adjustment sets the time that the pulse is switched into the regenerative amplifier and will eliminate the possibility of a secondary laser pulse being trapped in the regenerative amplifier.
4. Now reconnect the SDG II"OUT 3" BNC cable to allow the second Pockels cell to trigger. The timing will almost certainly be incorrect. Adjust the SDG II "OUT 3" delay control so that the intracavity pulse train now looks like the figure below.

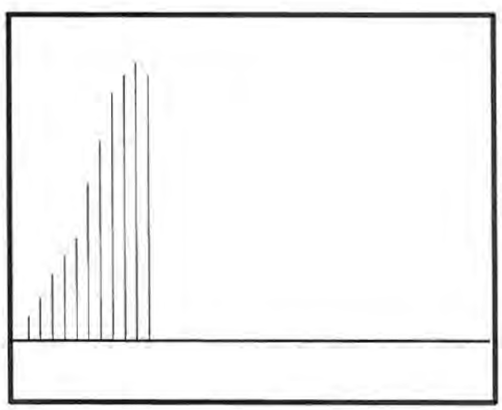


Figure 4.9: Intracavity pulse train with the timing correctly set

5. Now you must reposition the photodiode so that it is looking at the ejected pulse. Most probably you will see two pulses on the oscilloscope, separated by about 13ns, the round trip time if the regenerative amplifier resonator.

6. A small adjustment of the SDG II "OUT 3" delay control will ensure that a single pulse from the regenerative amplifier is ejected from the resonator.

7. Measure the pulse energy with a power meter. The energy measured should be close to or the same as that measured at installation.

5 Customer Service

At Coherent, we take pride in the durability of our products. We place considerable emphasis on controlled manufacturing methods and quality control. Nevertheless, even the finest instruments need occasional service.

5.1 Warranty

Coherent warrants to the original purchaser that the equipment is free from defects in material or workmanship. Coherent will, without charge, make any necessary repairs or replacement of parts to remedy such defect within one year, or 90 days in the case of optical surfaces, provided that Coherent in writing of the nature of such defect within one year, or 90 days for optical surfaces, following the date of original sale of the equipment. The foregoing warranty does not cover equipment which has been damaged by accident or improper use. Coherent does not assume any liability if adaptations are made or accessories attached to the equipment which impair or alter the normal functioning of the equipment. Any repair or adjustment by persons not expressly authorized by Coherent shall relieve Coherent of all obligations. The limited warranty and remedy contained in this paragraph are the only warranty and remedy pertaining to the equipment. COHERENT DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WARRANTY OR MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Coherent shall in no event be liable for any incidental, consequential or other damages or costs, lost profits or inconvenience occasioned by loss of the use of the equipment or labor expended by persons not so authorized by Coherent.

5.2 Return of the Instrument for Repair

Contact your nearest Coherent field sales office, service center, or local distributor for shipping instructions or an on-site service appointment. You are responsible for one-way shipment of the defective part or instrument to Coherent.

We encourage you to use the original shipping boxes during shipment. If shipping boxes have been destroyed or lost, we recommend you order new ones. We can return instruments only in Coherent containers.

COHERENT 5100 Patrick Henry Drive Santa Clara, CA 95054 Phone (408) 764-4000

2W-*Vitesse* Customer Test Data Sheet

Customer: . SSC S.O. # 131191 Date: 8/22/2006 7:51:24 AM

System S/N #: VITC2-NC29163 Technician: vienx CDRH: vienx Q.A.: spasovj

Vitesse System Specification

Parameter	Measured	Customer Spec.
Verdi Power	1.45 W	n/a
Modelocked Power	299.00 mW	>250 mW
CW Power	295.00 mW	n/a
Differential Power: ml-cw	4.00 mW	n/a
Wavelength	800.00 nm	800±1 nm
Bandwidth (FWHM)	12.50 nm	>10 nm
Differential Power, (CW breakthrough) - (Q-Switch)	4.00 mW	n/a
M^2	x: 1.04 y:1.01	<1.2
X Beam Diameter	$2\omega_{0x}$: 1.50 mm	1.25±0.25 mm
Beam Divergence	$2\theta_x$: 0.71 mrad	0.8 (+0.30 or -0.12) mrad
Beam Asymmetry $2\omega_{0x}/2\omega_{0y}$	1.34	1.1 (+0.3 or -0.2)
Rep Rate	80.17 MHz	80±1 MHz
Polarization Ratio	295.00:1	>200:1, Horizontal
Rms Noise 10 Hz - 10 MHz	0.07%	<0.1%
Verdi A/D	1355.00	<3000
PZTx/PZTy at delivery	x: 2.55 V y: 2.25 V	n/a
Baseplate Temperature	24.40 °C	n/a

Serial Number Information

Component	S/N
Vpuf Head	NC29163
Verdi Head	80627415
Power Supply	CV063000041
FAP-I	940980
Software Version	VIT 7.01
Verdi Head PCB	70154811 B
Vitesse Head PCB	70159148 C

Other Information

FAP-I Hours	322.56
Verdi Head PCB Hours	322.44

Slope Efficiency

Verdi Power (W)	Verdi Current (A)	Vitesse CW Power (mW)	Vitesse Modelocked Power (mW)	Slow Photodiode Voltage (V)	Center Wavelength (nm)	Bandwidth (FWHM) (nm)	Comment
1.25	11.95	221	246	4.05	799.6	9.90	Q-Switch Onset
1.35	12.01	259	276	4.57	799.8	11.49	
1.45	12.11	295	299	5.00	800.0	12.50	Operational Point
1.56	12.31	338	321	5.44	800.2	13.36	
1.67	12.47	379	339	5.82	800.5	14.10	CW-Breakthrough

Verdi System Specification

Parameter	Measured
Diode Current @ 2 W	13.26 A
Rollover Power	3.20 W
M^2 @ 2W	1.02
Beam Size @ O.C.: $2\omega_0$ @ 2W	2.24 mm
Beam Divergence 2Θ@ 2W	0.30 mrad
Waist Asymmetry @ 2W	1.03
RMS Noise (10 Hz- 2 MHz) in Light mode	2.2 W: 0.01%

Verdi Temperature Settings

Component	Optimized Temperature °C
Vanadate	35.00
LBO	151.99
Etalon	39.85
Diodes I/II	21.50

FAP Parameters

Parameter	Measured
Max Power	10.00 W
Diode Current @ Max Power	16.60 A
Threshold Current	7.31 A
Center Wavelength	809.17 nm
Spectral Width @ Max power	1.09 nm
Serial Number	940480

Declaration of Conformity
Application of Council Directives: 89 / 336 / EEC & 73 / 23 / EEC

COHERENT Inc.
Laser Group

5100 Patrick Henry Drive
Santa Clara, CA 95054
USA

Declares that the product:

Product Name: Vitesse Laser System

Model Number(s):
Vitesse 5 Watt System
Vitesse 2 Watt System
Vitesse XT 5W system

Conforms to the following standards:

EMC:
EN55011 (1991), Class B, Group 1
EN50082-1 (1992)
IEC801-2, Level x; 4KV Contact, 8KV Air
IEC801-3; Level 2
IEC801-4; Level 2; Power Line, 1KV; I/O, 0.5KV

Safety / LVD
EN61010-1 (1993): A2, (1995)
EN60825-1 (1994)

John Ambroseo
President, Coherent Laser Group
October 16, 2000

Jurgen Pfaff
V. P, Engineering
October 16, 2000

European Contact:
COHERENT GmbH
Dieselstrasse 5b
D-64807 Dieburg
Germany
Tel.: 06071-968-0

9/25/2006

QUALITY REPORT

AMPLIFIER REPORT # 234

LEGEND L-F-1k-HE 110 V

S/O #: **131191**

ENG: JOE RILEY

STATION:

QA BY: Wayne Polzin

Florida State University

of Line Items: 3

W/O #: 811695

COMPONENT	INTERNAL S/N:	TQC	S/W	TEMP	MANUAL	LABELS
LASER BENCH :	811695-01	☑				SSC.L-F-1K-HE.10117
DHSD S/N:		☐				
HSD #1 S/N:	706905-6	☑				706905-6
HSD #2 S/N:	706905-8	☑				706905-8
ECU S/N:	810301-C-01	☐		0.0		810301-C-01
SDG S/N:	757097-01	☑				757097-01
SSA S/N:		☐				
HVPS S/N:		☐				
OPERA S/N:		☐				
DFG S/N:		☐				
SFG S/N:		☐				
VIS/UV S/N:		☐				
EVO QA RPT#:	390					
EVO HEAD S/N:		☐				SSC..EV-30-110V.10244
EVO P/S S/N:	724946-CA-01	☐		LBO 324.8		724946-CA-01
LAPTOP S/N:	86QMHB1	☐				86QMHB1
CHILLER S/N:	76223-03	☐		CHILLER 20		76223-03

Q.A.

PV #1: — PV #1 MET ☐

PV #2: 0 — PV #2 MET ☐

EVO SPECS

SYSTEM HRS:	23:55:25	
Q-SW FREQ:	1	K
Q-SW P/W:	5	us
EVO P/W:		
POWER @ QA	0	W @ 15A
	0	W @ 20A
	20.5 W	19.8 A

PUMP 110 V

SEED LASER:	In House
SEED LASER S/N:	
TI-SAPH ROD:	H436CG2
POCKELS CELL 1:	02190-63
POCKELS CELL 2:	02190-66
STRETCH GRATING	8230.3
COMPR GRATING:	8236.2
PICO S GRATING:	
PICO C GRATING:	

CDRH CHECKLIST

PWR MTR S/N 0605H06

LAST CAL DATE 09/01/07

- ☑ LASER PERFORMS TO SPEC
- ☑ INTERLOCKS WORK
- ☑ EMISSION INDICATORS ON
- ☑ SHUTTERS FUNCTION
- ☑ VERIFY SIDE PANELS
- ☑ PAPERWORK COMP
- ☑ COSMETICS ACCEPTABLE
- ☑ BEAM FAULT TRIGGERS
- ☑ SINGLE SHOT CHECK
- ☑ CDRH LABELS
- ☑ WHEELIE BIN AND CE LABELS INSTALLED
- ☑ PASSED QA
- ☐ SIGN OFF REQ

DEVIATION #

SYSTEM SPECS

	FEMTO		PICO MASK	
EVO PUMP POWER:	20.5			W
@ CURRENT:	19.8			A
HE / HP LEG A POWER:	10.3		0.00	W
HE / HP LEG B POWER:	9.5		0	W
STRETCHER				
SEED POWER TO GRATING:	300			mW
STRETCHED POWER:	215			mW
RGA SEEDED				
REGEN OUTPUT POWER:	3.6			W
BUILD-UP TIME REDUCTION:	68			ns
COMPRESSED OUTPUT				
COMPRESSED OUTPUT POWER:	2.6	W		W
PULSE WIDTH (DE-CONVOLVED):	112	fs		ps
CONTRAST RATIO (PRE-PULSE):	1000	:		:
CONTRAST RATIO (POST-PULSE):	100	:		:
OUTPUT JITTER:	400			ps
SDG ns #1:	88			ns
SDG ns #2:	316			ns

STABILITY RUN

	Min	Max
RUN:	2.65	2.68
STABILITY:	0.56285	
RMS:	0.14	
# OF RUNS:	1	

LASER PASSED QA Q.A.: Wayne Polzin DATE : 9/25/06

9/25/2006

QUALITY REPORT

EVO - 30 1 kHz 110 V

EVO REPORT # : **390**

FLORIDA ST.

S/O # : **131191**

W/O # : **810192**

QA BY : ADRIAN ESTEBAN

ENG : SAM SUN

STATION #: #3

LEGEND AMP QA #:

COMPONENT	S/N	TQC	S/W	MANUAL	LABELS	P/V: N/A	P/V MET ☐
LASER HEAD S/N :	810192-01	☑		2.3	SSC.EV-30-110V.10244		
POWER SUPPLY :	724946-CA-01	☑			724946CA-01		
LAPTOP S/N :	86QMHB1	☑	4.1.6		86QMHB1	N/A	
CHILLER S/N :	768223-03	☑			768223-03		
DIODE HD #1 S/N :	744112H01	☑					
DIODE #1 :	32941						
DIODE #2 :	32942						
DIODE #3 :	32939						
ROD #1 S/N :	Y14725	☑					
DIODE HD #2 S/N :	N/A	☐					
DIODE #4 :							
DIODE #5 :							
DIODE #6 :							
ROD #2 S/N :		☐					
LBO HEATER S/N :	762407A-02	☐					
XTAL S/N :	0492						
Q-SW #1 :	26502						
Q-SW #2 :	26503						

72 hr RUN ☑ RUN TQC

RUN MIN :	22.5	@	20.7
RUN MAX :	23	@	20.7
RUN AVE :	22.75	STAB	1.10%
# OF RUNS :	1	hrs	72

PUMP POWER

IR W	AMPS 1	GR W 0
37.5:	N/A	0
45:		0
52.5:		0
60:		0
67.5:		0
75:		0
82.5:		0
90:		0
97.5:		0
105:		0
112.5:		0
120:		0
135:		0
150:		0
165:		0
180:		0
195:		0
210:		0
225:		0
240:		0
270:		0
300:		0
330:		0
360:		0
390:		0
420:		0
450:		0
480:	0	0 / 0

1 kHz 0 kHz

15 / 30 POWER @ Q.A.

	1 kHz	0 Hz
15 A PWR :	10.8	
20 A PWR :	20.8	
MAX PWR :	23	
@	21	
kHz :	1	0
us :	5.0	0
LBO temp :	324.8	0
kHz P/W :	175.4	0
CHILLER TEMP :	20	0

P/I Curve Ranking: 3.9

75 / 90 POWER @ Q.A.

POWER	CURR	LBO
N/A		

Q.A.

SYS HRS @ QA : 9.18

POWER METER S/N: COH-2354

LAST CAL DATE: 7/20/2006

NCMR #: N/A

CDRH CHECKLIST

- ☑ ALL CDRH LABELS PRESENT
- ☑ PASSED STAB RUN
- ☑ SYSTEM COSMETICALLY ACCEPTABLE
- ☑ LASER PERFORMS TO SPEC
- ☑ CHILLER WATER FLOW CHECK
- ☑ HEAD / SKINS INTERLOCK CHECK
- ☑ KEYSWITCH NOT REMOVABLE WHEN ON
- ☑ EMISSION INDICATION
- ☑ >2sec DELAY FROM START TO EMISSSION
- ☑ SHUTTER CLOSES @ LASER SHUT OFF
- ☑ BEAM POSITION CORRECT
- ☑ WHEELIE BIN AND CE LABELS INSTALLED

LASER PASSED QA: [stamp: 527 QA]

Q.A. : [signature] [stamp: 527 QA] **DATE :** 9/18/06